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for the Behavioral and Social Sciences**

Research Report 1674

Effect of Crew Composition on AH-64 Attack Helicopter Mission Performance and Flight Safety

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FOREWORD

The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) Rotary-Wing Aviation Research Unit at Fort Rucker, Alabama, is committed to enhancing the readiness of Army aviation units through development of effective techniques to train operational crews. The work in the area of crew coordination is a part of the work accomplished for meeting this objective. Considerable effort was expended to examine all of the available information on methods and techniques used to improve crew performance. The research described in this report is the culmination of a series of efforts to define the scope of the issues and empirically verify a training approach to improving crew performance. A combined effort between ARI and the Directorate of Evaluation and Standardization was undertaken to determine the effectiveness of crew coordination performance.

Operational AH-64 crews flew a series of missions under controlled conditions. Data were collected regarding the successful completion of those missions and several unexpected emergency situations. All crews flew all missions.

The results showed that crews trained with a specially developed set of training materials developed by ARI outperformed crews that were battle rostered. This finding indicated that battle rostering does not solve the crew coordination problem. The crew coordination training did result in improved crew performance.

These findings were used by the Army aviation community in changing the long-standing policy that required AH-64 crews to be battle rostered. It also demonstrated that well-structured analyses can be used to develop the training requirements necessary to satisfy the needs of aviation. The results of this work were briefed to the Commanding General, U.S. Army Aviation Center, in November 1993; the Commanding General, TRADOC, in January 1994; and the Chief of Staff, U.S. Army (CSA), in March 1994. The outcome of these briefings resulted in a tasker from the CSA to Training and Doctrine Command to examine the use of this methodology for other crewed systems.

EDGAR M. JOHNSON
Director

EFFECT OF CREW COMPOSITION ON AH-64 ATTACK HELICOPTER MISSION PERFORMANCE AND FLIGHT SAFETY

EXECUTIVE SUMMARY

Requirement:

This experiment investigated the mission performance and flight safety effects of two comparative methods of improving crew coordination: standardized training and battle rostering.

Procedure:

U.S. Army AH-64 aviators who had prior crew coordination training and recent flight experience as a battle-rostered crew were paired under two different conditions. Battle-rostered pairing of pilot and copilot gunner was based on the unit's operational aircrew designation. Pilot and copilot gunner crew members for nonbattle-rostered (mixed) crews were selected randomly from the battle-rostered crew population. Crews completed four different evaluation missions of comparable stress and difficulty in the AH-64 combat mission simulator (CMS). Subjects flew two evaluation missions as a battle-rostered crew and two evaluation missions as a mixed crew. Battle-rostered and mixed crew missions were counterbalanced to avoid an ordering effect. Each evaluation mission was directly observed by an instructor pilot (IP) evaluator, videotaped, and recorded by the flight simulator computer. These data enabled assessments of crew behaviors, task performance, mission performance, flight safety, and familiarity effect for each crew condition.

Findings:

Battle rostering is often perceived to improve crew performance. However, the experimental evidence did not show significant improvements in mission performance or flight safety. Crew performance of 13 well-defined crew coordination behaviors (Basic Qualities) and 25 aircrew training manual (ATM) tasks produced mixed results with no statistically significant difference between battle-rostered and mixed crews. Results that compared task performance with crew member self-ratings offered sufficient evidence to suggest that battle-rostered crews tend to revert to an implicit style of crew coordination more often than mixed crews do. The implicit crew coordination tendency demonstrated by battle-rostered crews adversely affected their performance of some ATM tasks. Although there were small but statistically significant differences in the area of weapons employment, crew

performance in five areas of mission performance (navigation, threat avoidance, evasion, inflight emergencies, malfunctions) produced mixed results with no other statistically significant difference. Battle rostering crews has a potential positive effect on gunnery performance.

Crew performance of flight safety intensive mission performance areas and safety-related ATM tasks produced mixed results with no statistically significant difference between battle-rostered and mixed crews. Since mission performance was similar in either crew configuration, the finding that crew members rate themselves 50% more confident when flying in their battle-rostered crew than in a mixed crew has negative implications. Overconfidence is suspected as a possible contributor to aviation accidents and crew complacency. Battle-rostered crews rated their workload as easier and their crew coordination style as more implicit than mixed crews.

Utilization of Findings:

The results of the experiment lead to the conclusion that standardized crew coordination training alone is achieving the Army's objective of improving crew performance. The mechanism for improving crew coordination, the Aircrew Coordination Exportable Training Package, is being fielded by the Army's Aviation Training Brigade, U.S. Army Aviation Center, Fort Rucker, Alabama.

Because standardized training was found to be the preferred solution for improving crew coordination, it is now more important than ever to make sure the training is fully implemented. This can be achieved by promulgating in key policy documents the requirement that all rated and nonrated crew members must complete the Army's Aircrew Coordination Training Program. Tendencies revealed during the experiment for crew members to revert to an implicit crew coordination style and individual rather than crew mission orientation make it important to develop and implement annual crew coordination refresher training. To fully implement the crew coordination training and evaluation system, it is necessary to incorporate the crew coordination Basic Qualities from the Aircrew Coordination Exportable Training Package into each ATM for annual evaluations.

Results of the experiment suggest that commanders may reduce risks and enhance areas of mission performance by battle rostering crews for short periods of time for specific missions, for example, gunnery. Commanders should be cautioned that making permanent crew assignments can potentially jeopardize both mission performance and flight safety.

EFFECT OF CREW COMPOSITION ON AH-64 ATTACK HELICOPTER MISSION PERFORMANCE AND FLIGHT SAFETY

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EFFECT OF CREW COMPOSITION ON AH-64 ATTACK HELICOPTER MISSION PERFORMANCE AND FLIGHT SAFETY

Introduction

The airline industry was the first to reveal evidence implicating crew coordination as a key factor in a number of commercial aviation major accidents and incidents. It was generally accepted that improved communication and coordination among individual crew members should improve flight safety and mission effectiveness. As a result, alternative means were sought to achieve better coordination among crew members. This research examines two comparative means of improving crew coordination: battle rostering and standardized training.

The battle-rostering approach permanently assigns specific crew members together as a crew. For example, Kanki and Foushee (1989) argued that commercial airline crews performed better, communicated more effectively, and made fewer errors when they had recently flown together. They used a high-fidelity flight simulator to observe the performance of airline crews that had previously flown together and crews that had not flown together. Their analysis focused on crew interaction as indexed by the communication process. Their research concluded that recent operating experience generates a type of "familiarity," which in turn, fosters improved information exchange and validation culminating in fewer crew errors.

Povenmire, Rockway, Bunecke, and Patton (1989) found that crew coordination performance correlated positively with B-52 crew tactical maneuvers and bombing accuracy. B-52 crews include six permanently assigned crew members. Observations were made using instruments from published Cockpit Resource Management (CRM) courses and mission performance outcome measures that were specially tailored to address crew task performance. Crews were observed conducting operational missions in the B-52 Weapon System Trainer. The research concluded that crew coordination training enhances combat mission performance of crews that fly together on a permanent basis.

During the period 1988-1994, the U.S. Army Research Institute (ARI) conducted a program of training research that responds to the Army's need for better crew coordination training. This program of research was conducted in close cooperation with the U.S. Army Aviation Center (USAAVNC) and its efforts to revise its training standards to reflect increased emphasis on crew-level performance.

The USAAVNC formed a working group in early 1990 to incorporate the results of the aircrew coordination research into

revisions of the total Aircrew Training Program (Department of the Army, 1992b) and Aircrew Training Manuals (ATMs) for all Army aircraft. The March 1992 revised Training Circular 1-210 introduced battle rostering and crew coordination as policies designed to improve effectiveness and safety by shifting the training emphasis from individual to crew-level performance.

Battle rostering, as defined in TC 1-210 (Department of the Army, 1992b), is "the designation of two or more individuals to perform as a crew and is fundamental to crew-level training. It (battle rostering) provides for the development and proficiency of critical skills. Crew coordination is enhanced by consistently battle rostering the same crew members." (p.1-11) The training circular also states the purpose and definition of crew coordination training. "Aircrew training must emphasize crew coordination as a vital part of the overall training program. It (crew coordination) is a set of principles, attitudes, procedures, and techniques which transforms individuals into an effective crew." (p.1-4)

The new crew coordination policy, designed to standardize crew behaviors, required development of a training course of instruction. Dynamics Research Corporation (DRC) worked closely with the USAAVNC working group to draft training and evaluation methods and materials for a crew coordination validation testbed effort. During the 1992 validation testbed, UH-60 crews from Fort Campbell, KY were battle rostered by their units for the experiment. Each crew completed four missions in the visual flight simulator with their battle-rostered crew member. The testbed demonstrated and validated the new field exportable program for training and evaluating crew coordination skills. Testbed results showed that the crews performed their missions significantly more effectively and safely after the training than before the training (Simon & Grubb, in preparation). The USAAVNC approved the Aircrew Coordination Exportable Training Package (ETP) (Pawlik, Simon, Grubb, & Zeller, 1992) late in 1992 and began implementing it Army-wide the following year.

Since promulgation of TC 1-210 (Department of the Army, 1992b), anecdotal data and aviation accident investigation reports suggested that battle rostering compromised operational safety. Discussions with U.S. Army Safety Center accident investigators indicated complacency and overconfidence were possible contributing factors. The U.S. Air Force conducted research comparing the effects of fixed versus formed aircrews on military transport accident rates. The research showed that mixed crews (as opposed to battle-rostered crews) were significantly safer (Woody, McKinney, Barker, & Clothier, 1994). The U.S. Navy Safety Center conducted a six-month analysis of naval aviation accident data to find out the effects of crew composition. Discussions with U.S. Navy Safety Center analysts

revealed that the results did not provide sufficient evidence to recommend a crewing policy. The USAAVNC notified all Army aviation units to defer crew readiness level progression and crew training pending explicit research results.

By the spring of 1993 it was becoming clear that two methods of improving crew coordination were available to the Army. First, the crew coordination improved through standardized instruction of crew members in a set of coordination behaviors and skills. In this case standardization of behavior was an essential ingredient. Second, battle rostering was believed to improve crew coordination by allowing crew members to develop familiar patterns of interaction and common understanding. With battle rostering it was possible that more idiosyncratic behavior would develop.

While these two methods were available, little was known regarding their relative effectiveness. Constraints on the validation experiment conducted earlier with the new field ETP (Pawlik et al., 1992) did not permit a comparative examination of battle rostering versus crew coordination training. On the other hand, anecdotal evidence suggested that some crews were benefiting from the Army's battle-rostering policy; yet, these same crews had not yet received the crew coordination training. Clearly, a comparative evaluation of battle rostering versus crew coordination training was needed to clarify the Army's policies in this area.

Accordingly, the USAAVNC asked ARI in the spring of 1993 to conduct such a comparative evaluation. Since crew coordination training had already been shown to produce significant improvements (Simon & Grubb, in preparation), and since the Army had already begun to field this training, the USAAVNC decided that this evaluation should consider battle rostering as a second variable. Thus, an experiment was designed to examine the contributions of battle rostering to crew performance. In this context, the present study addresses five hypotheses organized along different dimensions of crew performance:

1. Crew coordination behavior will be significantly improved through a combination of crew coordination training and battle rostering, as compared to the use of crew coordination training alone.

2. Crew flight task performance will be significantly improved through a combination of crew coordination training and battle rostering, as compared to the use of crew coordination training alone.

3. Mission performance will be significantly improved through a combination of crew coordination training and battle rostering, as compared to the use of crew coordination training alone.

4. Flight safety will be improved through a combination of crew coordination training and battle rostering, as compared to the use of crew coordination training alone.

A fifth hypothesis addresses those concerns specifically raised by recent accident experience with battle-rostered crews:

5. Crew overconfidence and complacency will be observed more frequently with battle-rostered crews, as compared to nonbattle-rostered crews.

This report describes the research conducted to compare the impact of battle rostering and crew coordination training on crew performance. The data was collected on operational crews under carefully controlled conditions performing specific ATM tasks in a simulated tactical situation.

Method

The research method included the use of a repeated measures design to compare crew performance effects under two different crew composition conditions: battle-rostered and mixed crews. The repeated measures design was counterbalanced across four mission scenarios and the two crew conditions. In addition to accounting for differences in mission scenarios and possible order and practice effects, the design provided two observations and multiple data points for each crew condition. Essential details of all aspects of the research method are described in this section of the report.

Design

A repeated measures experimental design, counterbalanced across four tactical mission scenarios and two crew configurations was developed for the research. Table 1 graphically portrays the experimental design.

Table 1

Experimental Design

Crews	Scenarios			
	1	2	3	4
1 - 4 9 & 10	Battle rostered	Battle rostered	Mixed	Mixed
5 - 8 11 & 12	Mixed	Mixed	Battle rostered	Battle rostered

Repeated measures was especially suitable to account for any minor differences in difficulty among the four scenarios while providing multiple data points from a reduced number of participating aircrews. The design provided two observations for the battle-rostered crew configuration and two observations for the mixed crew configuration to address the strength of effect. Counterbalancing these two crew configurations served to account for possible order and practice effects among participant aircrews and individual crew members.

Operational constraints required minor modification of a preferred experimental design to accommodate aircrew and simulator availability and unit training requirements. Principal among the constraints was that crews were scheduled for data collection missions by company rather than randomly across the battalion. This modification was made to permit company integrity for unit training during the three weeks of the experiment. Consequently, it was necessary to substitute two copilot gunners in mixed crews for four missions to implement the counterbalanced design. The substitution of technically current and crew coordination trained copilot gunners in mixed crews only had no effect on the results obtained from the repeated measures design. In all, 7 of the 24 mixed crews were formed from across companies rather than from within companies. Forming mixed crews from within companies was consistent with the unit's standard procedures but introduced into the experiment an aspect of potential difference in crew member familiarity. The AH-64 combat mission simulator (CMS) was available only for 13 days of data collection, eliminating the possibility of more than four observations per crew.

Each of the 12 crews completed each scenario to produce 48 data collection missions. Participating aviators conducted two missions in a battle-rostered crew and two missions in a mixed crew. Crew exposure to the evaluation scenarios was

counterbalanced; that is, crews given evaluation scenarios one and two for the battle-rostered missions, were given scenarios three and four for the mixed missions, and vice versa.

Subjects

Thirty-three aviators rated in the AH-64 Apache attack helicopter were selected to participate in the experiment. Participants included standardization instructor pilots (SIP), CMS operators, and subject aircrews.

Two SIPs from the USAAVNC's Directorate of Evaluation and Standardization (DES) and one Crew Coordination Cadre Training Team SIP were combined with unit instructor pilots (IP) to evaluate crew performance. All five of these IP evaluators were selected based on their training and experience in using the Army's crew coordination evaluation procedures. Two AH64CMS subject matter experts were selected to program and control the evaluation mission scenarios.

Twelve battle-rostered aircrews, each consisting of a pilot and copilot gunner (CPG), were identified by their unit as subject aircrews for the experiment. The experiment specified that subject aircrews meet two requirements: (a) each crew member had completed training in the Army's Aircrew Coordination Exportable Training Package (Pawlik et al., 1992), and (b) the subject aircrew had flown at least one mission as a battle-rostered crew in the 60 days prior to the experiment.

The initial set of 12 aircrews consisted of four battle-rostered crews from each of the battalion's three attack helicopter companies. Battle-rostered crew pairings of pilot and CPG were based on the unit's operational aircrew designation. Crew members for mixed crews were selected randomly within each company.

Unit operational and training requirements made it necessary to substitute two CPG for the primary crew member in four of the mixed crews. These alternate subjects fully met the requirements of the experiment. The final subject aircrew pool consisted of 12 pilots and 14 CPG. Three subject aircrew members were not available for the exit interview and self-evaluation phase of the experiment due to temporary duty assignments. Selected demographic information for participants in the experiment is shown in Table 2.

Table 2

Experiment Participants

	Number	Ranks	AH-64 flight hours
IP evaluators	5	MAJ (1), CW4 (1), CW3 (2), CW2 (1)	Range: 500-2000 Average: 1180
CMS operators	2	CW3 (1), CIV (1)	Range: 1000-1540 Average: 1270
Crew members			
- Pilot	12	CW3 (1), CW2 (11)	Range: 145-1200 Average: 500
- CPG	14 ^a	CPT (3), LT (3), CW4 (2), CW3 (2), CW2 (4)	Range: 70-1000 Average: 300

^aIncludes 2 substitute CPG in 4 mixed crew missions.

Equipment

AH64CMS. The AH64CMS is a simulation system designed for training in the use of AH-64 Apache helicopters. The CMS simulates the Apache helicopter and its related systems to the same level of performance as found in the operational systems. The CMS consists of two separate compartments for the pilot and copilot gunner, each having a six-degree-of-freedom hydraulic motion system. Each compartment includes a crew member station, pilot or copilot gunner, in the forward portion and instructor/operator and observer stations in the rear portion. Each compartment is equipped with a visual system that simulates natural helicopter environment surroundings. The CMS provides normal and emergency procedural mission and weapons delivery training. Additional capabilities include navigation, instrument flight operation, day, dusk, and night visual flight operations, ordnance delivery, and aircraft survivability systems of the attack helicopter. In addition, the CMS can be used to simulate tactical threat systems.

Video recording and playback. Each simulator mission was observed and recorded using four video cameras multiplexed onto one video picture (Figure 1). All intercom, radio communications, and aural warnings were recorded onto the videotape. One camera was placed in each simulator compartment and aimed to provide a high-over-the-shoulder view of each crew member. Two cameras were placed in the instructor/operator station of the copilot gunner compartment and aimed at monitors

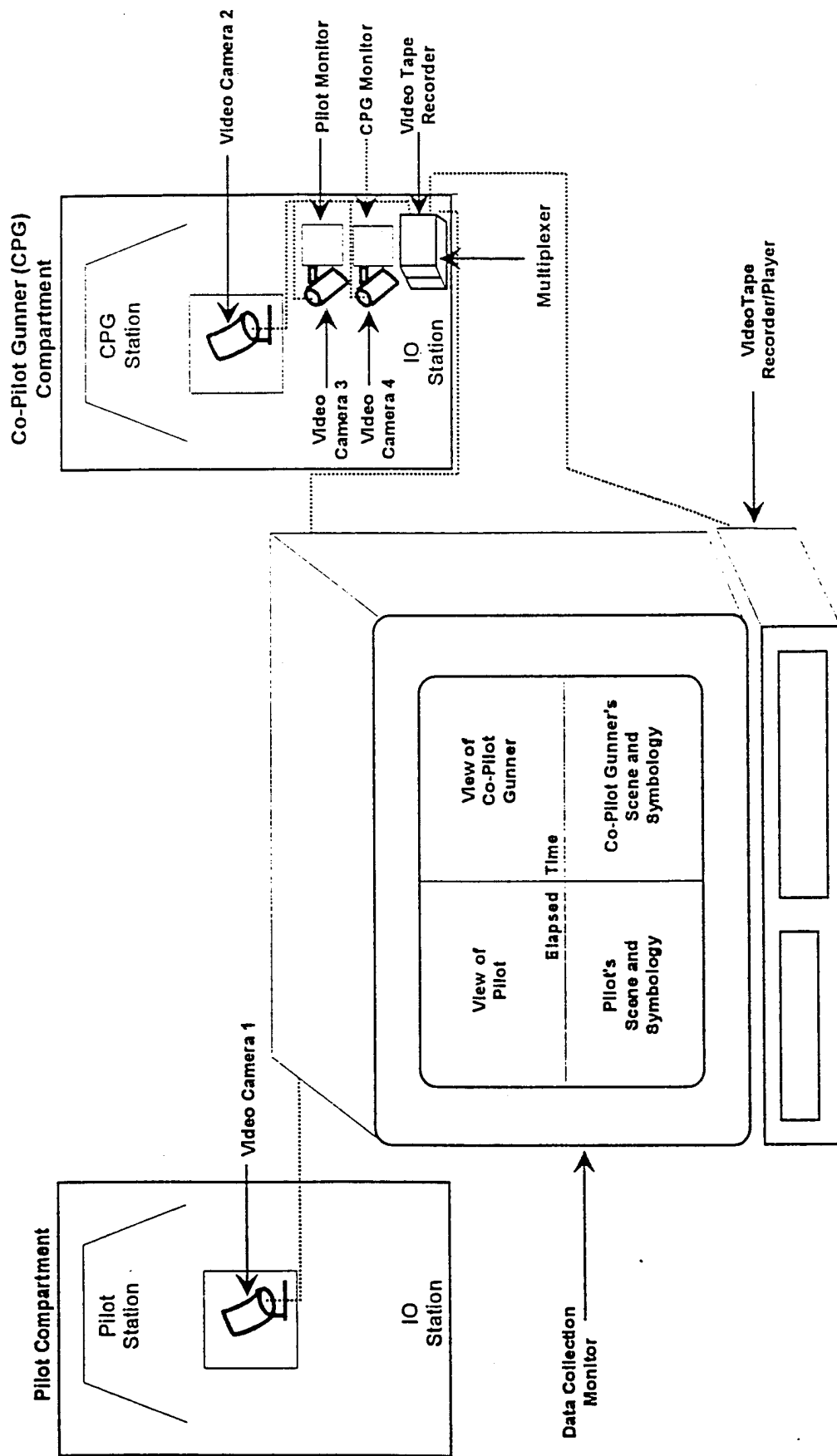


Figure 1. Illustration of video recording and playback equipment.

to capture each crew member's visual field of view and symbology overlay. Videotape players and monitors were located in crew after action review, IP evaluator, and data collector areas to review crew performance after each mission. A notebook computer with data logger software designed for the experiment was used to synchronize data collector's written comments with the mission time overprinted on the videotape.

Materials

Training. The training and evaluation components of the Aircrew Coordination Exportable Training Package (Pawlik, et al., 1992) were implemented as published. These training materials are described in two separate reports previously developed for ARI (Grubb, Simon, Leedom, & Zeller, 1993; Pawlik, Simon, Grubb, & Zeller, in preparation).

Scenarios. Four attack helicopter tactical scenarios were developed for the crew-level evaluations to assess changes in crew mission performance and flight safety. Scenario objectives and tasks were designed to present four equally difficult missions to the aircrews. The data collection scenarios included various combinations of the mission segments and activities shown in Table 3.

Each of the four evaluation scenarios was designed to test the subject aircrews on their ability to plan and execute a typical attack helicopter mission at night in a mid-intensity threat environment. Each scenario involved multiple AH-64 aircraft with the evaluated crew acting as either company or heavy team lead. The scenarios, lasting approximately an hour and fifteen minutes each, included numerous crew coordination related ATM tasks and required the crew members to interact with one another to successfully accomplish the mission.

Scenarios one and three originated in forward assembly areas and required the crew to navigate to a forward arming and refueling point (FARP) for ammunition and fuel before proceeding to prebriefed battle positions. En route to the FARP, the crews experienced a minor malfunction of an aircraft system, which was administratively corrected once they arrived at the FARP. After occupying two different battle positions and engaging a variety of armor, artillery, air defense, and mechanized targets, the crews encountered deteriorating weather conditions while returning to the FARP and inadvertently entered instrument meteorological conditions. The missions ended when the crew completed a non-precision instrument approach to a recovery airfield.

Table 3

Data Collection Scenario Outlines

Mission segments	Activities					
	Navigation	Threat avoid & evade	Minor/Major malfunction	Occupy battle position	Acquire, identify, & engage targets	Unexpected events
Premission planning	Plan and rehearse all activities					
Forward Assembly Area (FAA) to rearm & refuel	Scenario 1 Scenario 3	All	Minor-Scenario 1 Scenario 3			Scenario 1 Scenario 3
Rearm & refuel to battle position	Scenario 1 Scenario 3	All				
Holding area to FAA/Battle position	Scenario 2 Scenario 4	All		All	All	
Battle position to battle position	All	All	Minor-Scenario 2 Scenario 4	All	All	Scenario 2 Scenario 4
Battle position to rearm & refuel/recovery airfield	All	All	Major-Scenario 2 Scenario 4			All Scenario 1 Scenario 3

The other two scenarios started in holding areas with the aircraft fully loaded with fuel and ammunition. In scenario two, the crews navigated to a forward assembly area to receive a mission update before proceeding to prebriefed battle positions. In the initial battle position, the crews engaged armor, mechanized, and air defense targets before proceeding to a successive battle position. While navigating between battle positions, the crews experienced a minor malfunction of an aircraft system. Returning to the FARP at the end of the mission, the crews experienced a major malfunction of an aircraft system.

In scenario four, the crews navigated directly to their initial battle position. There, the crews engaged armor, mechanized, and air defense targets before being ordered to accompany the scout aircraft to confirm a suspected enemy airmobile assault behind friendly lines. While en route to the second battle position, the crews experienced a minor malfunction of an aircraft system. In the second battle position, the crews engaged light armored vehicles and attack and utility helicopters conducting an airmobile assault. While returning to the FARP at the end of the mission, the crews experienced a major malfunction of an aircraft system.

Rating instruments and interview guide. Measures similar to those previously used for the utility helicopter validation testbed (Simon & Grubb, in preparation) were developed and tested to confirm their accuracy in data collection using the AH64CMS. Crew behaviors (Basic Qualities), ATM task performance, mission performance, and familiarity effects measures are defined later as the dependent variables to address experiment hypotheses. Following is a description of the rating instruments and interview guide for measures used in the experiment.

Two forms from the Aircrew Coordination Exportable Training Package (Pawlik et al., 1992) were used to record crew behaviors and performance: (a) DA Form 7121-R (Department of the Army, 1992a) entitled Battle-Rostered Crew Evaluation/Training Grade Slip and (b) the Aircrew Coordination Training Grade Slip based on DA Form 5882-R (Department of the Army, 1992a) entitled Maneuver/Procedure Grade Slip for AH-64 Aviators.

The Battle-Rostered Crew Evaluation/Training Grade Slip (Pawlik et al., 1992) allowed IP evaluators to make written comments and record a grade for the overall flight (Figure 2). More detailed information was recorded and attached by way of the Aircrew Coordination Training Grade Slip (Pawlik et al., 1992), (Figure 3), which provided IP evaluators with space for crew information, multiple entries for grading each task, and a look-up table of crew coordination behaviors at the bottom of each page. A grade block was provided to enter a summary rating for

BATTLE-ROSTERED CREW EVALUATION/TRAINING GRADE SLIP For use of this form, see Aircraft ATM; the proponent agency is TRADOC					
BATTLE-ROSTERED CREW EXAMINEES/ TRAINEES	NAME		RANK		
	PC:				
	PI:				
	DUTY SYMBOL	NONRATED CREW MEMBERS NAME		RANK	
	UNIT:				
EVALUATOR/ INSTRUCTOR	NAME		RANK		
	UNIT:				
CREW DATA					
TOTAL BATTLE-ROSTERED CREW HOURS			DATE DESIGNATED A BATTLE-ROSTERED CREW:		
PURPOSE: EVALUATION/TRAINING					
TIME TODAY:			CUMULATIVE TIME:		
TYPE AIRCRAFT: _____ <div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> CREW TASK 1 _____ D/N/NVD CREW TASK 2 _____ D/N/NVD CREW TASK 3 _____ D/N/NVD CREW TASK 4 _____ D/N/NVD CREW TASK 5 _____ D/N/NVD </div> <div style="width: 45%;"> CREW TASK 6 _____ D/N/NVD CREW TASK 7 _____ D/N/NVD CREW TASK 8 _____ D/N/NVD CREW TASK 9 _____ D/N/NVD CREW TASK 10 _____ D/N/NVD </div> </div> <div style="display: flex; justify-content: space-between; margin-top: 5px;"> DAY _____ NIGHT _____ WX _____ SIMULATOR _____ NVG _____ NVS _____ </div>					
EVALUATOR/INSTRUCTOR RECOMMENDATIONS					
<input type="checkbox"/> (ISSUE) (VALIDATE) CREW QUALIFICATIONS					
<input type="checkbox"/> (SUSPEND) (REVOKE) CREW QUALIFICATIONS					
<input type="checkbox"/> REQUIRES ADDITIONAL (FLIGHT) (ACADEMIC) (SIMULATION DEVICE) TRAINING					
<input type="checkbox"/> SEE BACK FOR COMMENTS					
<p>I HAVE DEBRIEFED THE EXAMINEES/TRAINEES AND INFORMED THEM OF THEIR STATUS. EVALUATOR'S/INSTRUCTOR'S SIGNATURE: _____</p> <p>WE HAVE BEEN DEBRIEFED BY THE EVALUATOR/INSTRUCTOR AND UNDERSTAND OUR CURRENT STATUS.</p> <p>PC'S SIGNATURE: _____</p> <p>PI'S SIGNATURE: _____</p> <p>NONRATED CREW MEMBER'S SIGNATURES: _____ _____</p> <p>OVERALL GRADE FOR THIS FLIGHT IS: S U NA DATE: _____</p>					

DA FORM 7121-R, MAR 92

Figure 2. Battle-rostered crew evaluation/training grade slip (page 1 of 2).

MANEUVER/PROCEDURE GRADE SLIP FOR AH-64 AVIATORS												
For use of this form, see Aircrew Coordination Exportable Training Package and TC 1-214												
P _____			Date _____									
CPG _____												
Instructor or evaluator will sign in the first unused block of each area trained or evaluated												
NO.	STAN EVAL/TRAINING TASKS	GR	NO.	STAN EVAL/TRAINING TASKS	GR							
1	CREW MISSION BRIEFING		37	IHADSS OPERATIONS								
2	PLAN VFR FLIGHT		38	DATA ENTRY PROCEDURES (FS)								
3	DA FORM 5701-R (PPC)		39	ACFT POSITION UPDATE (FS)								
4	PREFLIGHT INSPECTION		40	TARGET STORE (FS)								
5	ENG START, RUN-UP, T/O CKS		41	FIRING POSITION OPS								
6	HOVER POWER CHECK		42	ENGAGE TGT WITH HELLFIRE								
7	NORMAL TAKEOFF		43	ENGAGE TGT WITH ARCS								
8	TRAFFIC PATTERN FLIGHT		44	ENGAGE TGT WITH AWS								
9	FUEL MANAGEMENT PROCEDURES		45	WPNS INITIALIZATION								
10	DOPPLER NAVIGATION (FS)		46	TARGET HANDOVER								
11	BEFORE LANDING CHECK		47	IHADSS TARGET TRACKING								
12	VMC APPROACH		48	ORAL EVALUATION								
13	CONFINED AREA OPERATIONS		49									
14	SLOPE OPERATIONS		50									
15	TERRAIN FLIGHT TAKEOFF		51									
16	TERRAIN FLIGHT		NO.	NIGHT/NVD/EVAL/TRAINING TASKS	GR							
17	NOE DECELERATION		1	CREW MISSION BRIEFING								
18	TERRAIN FLIGHT APPROACH		2	NVS OPERATIONAL CHECKS								
19	STANDARD AUTOROTATION		3* +	GROUND TAXI								
20	SIM SINGLE ENG FAILURE ALT		4*	HOVER POWER CHECK								
21	SIM SINGLE ENG FAILURE OGE		5* +	HOVERING FLIGHT								
22	SINGLE-ENGINE LANDING		6* +	NORMAL TAKEOFF								
23	ECU LOCKOUT OPERATIONS		7	ROLLING TAKEOFF (BS)								
24	TERRAIN FLIGHT NAVIGATION		8 +	TRAFFIC PATTERN FLIGHT								
25	EMERGENCY PROCEDURES		9*	FUEL MANAGEMENT PROCEDURES								
26	IIMC PROCEDURES/VHIRP		10*	PILOTAGE & DEAD RECKONING								
27	MASKING AND UNMASKING (BS)		11*	DOPPLER NAVIGATION								
28	MAJ US/ALLIED/THREAT EQUIP		12* +	VMC APPROACH								
29	ACFT SURVIV EQUIP (BS)		13*	CONFINED AREA OPERATIONS								
30	AFTER-LANDING TASKS		14*	SLOPE OPERATIONS								
31	MARK XII IFF SYSTEM		15*	TERRAIN FLIGHT TAKEOFF								
32	TADS OPERATIONAL CHKS (FS)		16*	TERRAIN FLIGHT								
33	TADS BORESIGHTING (FS)		17*	NOE DECELERATION								
34	TADS SENSOR OPERATIONS (FS)		18*	TERRAIN FLIGHT APPROACH								
35	IHADSS BORESIGHT		19* +	SIM SINGLE-ENG FAILURE ALT								
36	IHADSS VIDEO ADJUSTMENTS		20* +	SINGLE-ENGINE LANDING								
AIRCREW COORDINATION BASIC QUALITIES												
1. CREW CLIMATE	2. PLAN RE- HEARSE	3. DECISION TECH	4. WORK LOAD	5. UNDEP EVENTS	6. INFO XFER	7. SIT AWARE	8. COMM ACK	9. INFO SOUGHT	10. CROSS MON- ITOR	11. INFO OF- FERED	12. ADVOC/ ASSERT	13. AAR

AIRCREW COORDINATION TRAINING GRADE SLIP

Figure 3. Aircrew coordination training grade slip (page 1 of 2).

MANEUVER/PROCEDURE GRADE SLIP FOR AH-64 AVIATORS												
NO.	NIGHT/NVD EVAL/TRAINING TASKS	GR	NO.	TRNG/MISSION/ADDITIONAL TASKS	GR							
21*	TERRAIN FLIGHT NAVIGATION		1	DD FORM 365-4								
22*	EMERGENCY PROCEDURES		2	SIM MAX PERF T/O (BS)								
23	UNUSUAL ATTITUDE RECOVERY		3	DECELERATION/ACCEL (BS)								
24*	IIMC PROCEDURES/VHIRP		4	ROLL-ON LANDING (BS)								
25	MASKING & UNMASKING (BS)		5	TERRAIN FLT MISSION PLAN								
26	TADS OPERATIONAL CKS (FS)		6	HIGH-SPEED FLIGHT								
27	TADS BORESIGHT (FS)		7	SIM SINGLE ENG FAILURE IGE								
28	TADS SENSOR OPERATIONS (FS)		8	STABILATOR MALF PROCEDURE								
29	IHADSS BORESIGHTING		9	INSTRUMENT TAKEOFF (BS)								
30	IHADSS VIDEO ADJUSTMENTS		10	TWO-WAY RADIO FAILURE								
31	IHADSS OPERATIONS		11	PINNACLE OR RIDGELINE OPS								
32*	NVG FAILURE (FS)		12	HIGH/LOW G FLIGHT								
33	ORAL EVALUATION		13	EVASIVE MANEUVERS (BS)								
34			14	MULTIAIRCRAFT OPERATIONS								
35			15	CALL FOR/ADJUST IND FIRE								
36			16	VIS SIGNAL TECHNIQUES (FS)								
37			17	LASER SPOT TRACKER OPS (FS)								
NO.	INST EVAL/TRAINING TASKS	GR	18	FARP PROCEDURES								
1	CREW MISSION BRIEFING		19	ACTIONS ON CONTACT								
2	IFR FLIGHT PLANNING		20	ID TARGETS WITH TADS (FS)								
3	ENG START, RUNUP, T/O CKS		21	SELECT APPROPRIATE WPN SYS								
4	FUEL MANAGEMENT		22	TGT TRACKING WITH TADS (FS)								
5	BEFORE-LANDING CHECK		23	OPERATE ONBD RECORDER (FS)								
6	SIM SINGLE-ENG FAILURE ALT		24	DIVING FLIGHT (BS)								
7	EMERGENCY PROCEDURES		25	TECHNIQUES OF MOVEMENT (BS)								
8	RADIO NAVIGATION		26	NEGOTIATE WIRE OBSTACLES								
9	HOLDING PROCEDURES		27	TACTICAL COMMO AND ECCM								
10	UNUSUAL ATTITUDE RECOVERY		28	TRANS TACTICAL REPORT (FS)								
11	RADIO COMMUNICATIONS PROC		29									
12	NONPRECISION APPROACH		30									
13	PRECISION APPROACH		31									
14	IIMC PROCEDURES/VHIRP		NOTES: * REQUIRED FOR NVG EVAL + REQUIRED FOR NIGHT EVAL ENTER S+, S, S-, OR U IN GRADE BLOCK. IF GRADE IS S- OR U DUE TO AIRCREW COORDINATION INCLUDE BASIC QUALITY NUMBER(S)									
15	AFTER-LANDING TASKS											
16	ORAL EVALUATION											
17												
18												
AIRCREW COORDINATION BASIC QUALITIES												
1. CREW CL-MATE	2. PLAN RE-HEARSE	3. DECISION TECH	4. WORK LOAD	5. UNEXP EVENTS	6. INFO XFER	7. SIT AWARE	8. COMM ACK	9. INFO SOUGHT	10. CROSS MON-ITOR	11. INFO OFFERED	12. ADVOC/ASSERT	13. AAR
GRADE												

PAGE 2. AIRCREW COORDINATION TRAINING GRADE SLIP

Figure 3. Aircrew coordination training grade slip (page 2 of 2).

each crew coordination behavior at the bottom of the last page. For purposes of this report, these two forms are collectively referred to as the grade slip.

Based on previous research, the USAAVNC defines, trains, and evaluates crew coordination behaviors in terms of 13 Basic Qualities. Each Basic Quality was rated by an IP evaluator on a seven-point scale and recorded on the grade slip. The seven-point scale was anchored at the 1, 4, and 7 levels with specific behavioral descriptions of performance at those levels. IP evaluators were instructed to interpolate ratings of 2, 3, 5, and 6 from the descriptions given at the 1, 4, and 7 levels as being somewhat better or worse than the anchored description. The numbers associated with the Basic Quality ratings were 1 = Very Poor, 2 = Poor, 3 = Marginal, 4 = Acceptable, 5 = Good, 6 = Very Good, and 7 = Superior. The Basic Quality definitions, anchor descriptions, and detailed rating guidelines are provided in the Aircrew Coordination Exportable Training Package (Pawlik et al., 1992).

Aircrew tasks contained in the ATM for the AH-64, TC 1-214 (Department of the Army, 1992a) were used as basis for determining crew performance. All ATM tasks include both a crew coordination and a technical flight skill component. IP evaluators rated crews on various ATM tasks but were required to rate crews on 25 selected tasks for each evaluation mission. ATM task performance was graded on a four-point scale: S+, S, S-, and U. When a crew received a grade of S- or U due to crew coordination, IP evaluators noted on the grade slip which Basic Qualities contributed negatively to the task grade.

Scenario worksheets were developed as a means for IP evaluators to record crew mission performance ratings. The worksheets were designed to follow the segments of each scenario (Figure 4). Circle or fill-in type entries were used to facilitate rapid and accurate recording of IP evaluator entries in the following categories of crew mission performance: navigation, weapons employment, threat, unexpected events, and instrument approach. Rating scales describing levels of performance within each mission category were used to measure crew performance. For example, the rating scale for the planning dimension of the instrument approach category describes four levels of performance. A superior rating required both crew members to review, discuss, and rehearse the approach. A good rating was achieved when one crew member reviewed the approach, briefed the other crew member, and then talked him through the approach. A poor rating was assigned a crew where one crew member reviewed the approach and talked the other through it. Finally, an unsatisfactory rating was assigned when one crew member reviewed and executed the approach without assistance.

AH-64 SCENARIO #1 (CMS PHASE II)

SEGMENT 5: Movement from the BP to the FARP

DESCRIPTION: The segment begins as the crew departs the successive BP enroute to the FARP. During this segment, the crew encounters an inadvertent entry into instrument meteorological conditions (IMC). The crew must then plan and execute a nonprecision instrument approach to transition back to visual meteorological conditions (VMC). The segment ends when the crew completes a safe landing.

TASK 1083 Perform inadvertent IMC procedures/VHIRP

GRADE: S+ S S- U
Basic Qualities: __, __

NOTES:

- VHIRP steps accomplished? __ of 5
- Successful transition from VMC to IMC? Yes/No (Circle one)

Crew approach planning (Circle one)

- 3 Both crew members review, discuss, and rehearse the approach
- 2 One crew member reviews the approach, briefs the other prior to executing the approach, then talks the other through it
- 1 One crew member reviews the approach and talks the other through it
- 0 One crew member reviews and executes the approach with no assistance from the other

TASK 1081 Perform nonprecision approach

GRADE: S+ S S- U
Basic Qualities: __, __

NOTES:

- Inbound leg properly timed ? Yes/No (Circle one)
- Aircraft in position to safely land? Yes/No (Circle one)

Figure 4. Scenario worksheet.

Interview guides used in the experiment to measure crew familiarity consisted of two parts. First, each individual was asked to rate his performance as a member during the data collection missions. A questionnaire was used to collect crew members' perceptions of how well they performed the crew coordination Basic Qualities in terms of effectiveness, difficulty, and style during their battle-rostered and mixed crew missions. Table 4 shows the crew member self-rating areas, definitions for each area, and the rating scale. An example of the crew member self-rating questionnaire is presented in Appendix A. Second, crew members were asked in a group forum to respond to open-ended questions about crew coordination training and battle rostering policy.

Table 4

Crew Member Performance Self-rating Areas

Crew members (n=23)

Self-rating area	Description	Rating scale
Effectiveness	Own view as to how well you performed this aspect of crew coordination as a crew	1 = Very poor 7 = Superior
Difficulty	Own view as to the level of difficulty you encountered in performing this aspect of crew coordination	1 ^a = Very easy 7 ^a = Very Difficult
Style	Own view as to the manner in which you performed this aspect of crew coordination; that is, how explicitly were crew coordination actions carried out during the missions	1 ^a = Consistently explicit 7 ^a = Consistently implicit
Explicit style	Crew coordination was conducted in an open and observable manner; nothing was taken for granted; crew coordination was accomplished "by the book"	
Implicit style	Crew coordination was conducted in a nonobservable and subconscious manner; other crew member's understanding was assumed to be consistent with yours; relied on mutual anticipation based on previous flight experiences	

^aThe difficulty and style ratings were translated for computer analysis so that 1 = Difficult and 7 = Easy; and 1 = Implicit and 7 = Explicit, respectively.

Procedure

Training. Procedures to prepare for and execute the research included training and data collection activities. Major activities for both the training and experiment phases of the research are presented in Table 5.

The first phase of the research was conducted from May to July 1993 to provide all participating crew members with crew coordination training. During this phase, project staff instructed DES SIPs to assist in evaluating the unit instructor evaluation and training missions. Project staff and DES then instructed and evaluated the participating IPs and unit trainers (UT). Instructor teams consisting of unit IPs and UTs were formed to team-teach the unit aviators. All participating AH-64 aircrews were certified as having successfully completed the Army's Aircrew Coordination Exportable Training Package (Pawlik et al., 1992).

Table 5

Research Activities

Training phase (May to July 1993)	Experiment phase (October to November 1993)
Evaluator training <ul style="list-style-type: none">• DES SIPs	Data collection team training <ul style="list-style-type: none">• IP evaluators• CMS operators
Instructor training <ul style="list-style-type: none">• Project staff• IPs and UTs	
Aircrew Training ^a <ul style="list-style-type: none">• AH-64 crews• OH-58 crews• UH-60 crews	Experiment missions flown <ul style="list-style-type: none">• AH-64 battle rostered crews• AH-64 mixed crews
Participant exit interviews (Training) ^a	Participant exit interviews (Experiment)

^a Includes battalion staff personnel.

Several months elapsed between the training and the experimental evaluation. During this time, subject aircrews were able to refine their crew coordination skills and to fly as battle-rostered crews. No structured process was followed nor required.

The experiment phase of the research was initiated in late October 1993 by training a fully integrated data collection team of IP evaluators, CMS operators, and project staff for the experiment. Key project staff instructed data collection team members to provide them with a thorough understanding of the data collection plan, procedures, and materials and the knowledge necessary to evaluate crew performance and collect performance data. The instruction included classroom discussion and practice exercises on the data collection measures, methods, and data collector responsibilities. Data collection team training concluded with a full dress rehearsal of all four data collection scenarios to evaluate and critique data collection procedures and data collection team performance.

Data collection. A data collection plan was developed and implemented to provide a combination of data collection means to ensure reliable data for each measurement area. Most of the data collection methods had been used successfully in previous efforts related to the aircrew coordination training validation testbed (Simon & Grubb, in preparation). Thus, debugging the data collection methods required minimal effort, and it was known that the methods were valid. Data collection procedures produced a cross-check among collection sources without burdening any one source or requiring extensive review of mission videotapes. Table 6 shows the collection source to measurement area relationships.

The data collected for each mission in the experiment included video recording, live observation, CMS-generated documentation, and post-mission interviews. Three videotapes were used to document all aspects of each mission. One tape was used to record the crew's premission planning and rehearsal and the crew-level after-action review. Two separate but simultaneously recorded videotapes were used to record the flight in the CMS. One flight videotape was used by project staff observers in conjunction with data logger entries and by IP evaluators to debrief each crew. Project staff and IP evaluators used the second flight videotape as a backup in the event of defects in the primary videotape.

Live observation data were collected by IP evaluators, CMS operators, and project staff. IP evaluators used scenario worksheets and grade slips to record data for all measurement areas. The CMS operator controlled the preprogrammed scenario for each data collection mission. In addition to adding realism

Table 6

Data Collection Sources and Measures

Measure	Collected by			
	IP evaluator	CMS	Project staff	Partici- pant
Basic Qualities	X			X
ATM Tasks	X			
Mission performance	X	X	X	
Familiarity effects				X

by role playing other aircraft in the flight and external tactical elements, the CMS operator directed preselected display screens to a printer to collect specific mission performance data. Project staff recorded data and comments corresponding to the flight videotape for each mission.

The data collection team evaluated the subject aircrews as they completed each of the four scenarios to produce 48 data collection missions. Subject aircrews conducted two missions in a battle-rostered crew and two missions in a mixed crew configuration.

Exit interviews. When all of the data collection missions were completed for the experiment, crew members and IP evaluators participated in an exit interview. Crew members were asked to self-rate their performance during the data collection missions. Crew members and IP evaluators were asked to respond to open-ended questions about crew coordination training and battle-rostering effects and policies. Several days prior to the exit interview, participants were given the open-ended interview questions to make notes on the items they wanted to discuss. IP evaluators and many of the crew members wrote responses to the interview questions and gave them to the project staff. Three groups of eight crew members and one group of seven IP evaluators and CMS operators were interviewed. Each group exit interview lasted approximately 50 minutes.

The project staff facilitated the exit interview process by recording the group's responses and discussions. After the crew

member self-ratings plus participant written responses and project staff notes were collected, self-rating data were analyzed for insights into crew performance. Data from the open-ended questions were edited for readability and compiled to eliminate duplicate responses. Summaries of responses to open-ended questions are presented in Appendix B.

Variables

Independent variable. Crew condition, that is, battle rostered or mixed, was the independent variable in this experiment. To control the crew condition variable throughout the experiment, each subject crew was given a battle-rostered crew number from 1 to 12. During the experiment, each battle-rostered crew flew two evaluation missions with their battle-rostered crew member, i.e., 24 battle rostered crew missions. Copilot gunners were randomly paired with pilots within each company to form mixed crews, i.e., mixed crew condition. Each mixed crew was given a crew number from M1 to M24 and flew one evaluation mission during the experiment or 24 mixed crew missions. Table 7 shows the distribution of subject aircrews by attack helicopter company.

Table 7

Subject Aircrews by Attack Helicopter Company

Attack helicopter company	Battle-rostered crews	Mixed crews
A	1 - 4	M1 - M8
B	5 - 8	M9 - M16
C	9 - 12	M17 - M24
Totals	12 ^a	24

^aEach battle-rostered crew completed two evaluation missions.

To avoid potential bias, data collection missions were identified by mission numbers 1 through 48 rather than by crew number. Also, IP evaluators were scheduled to avoid evaluating the same crew twice.

Dependent variables. The dependent variables for this experiment were crew behaviors (Basic Qualities), ATM task performance, mission performance, and negative familiarity effects (Table 8).

Table 8

Dependent Variables

Behaviors (Basic Qualities)	ATM task performance	Mission performance	Familiarity effects
Establish and maintain flight team leadership and crew climate	Crew Mission Briefing DA Form 5701-R (PC) Engine-start, run-up, hover, and before take-off checks	Navigation	Overconfidence
Premission planning and rehearsal accomplished	Hover Power Check Fuel Management Procedures Doppler Navigation Terrain Flight Mission Planning	Weapons employment Threat avoidance and evasion	Complacency Implicit coordination
Selection of appropriate decision-making techniques	Terrain Flight Mission Planning	Unexpected events	Non-standard procedures
Prioritize actions and distribute workload	Terrain Flight Takeoff Terrain Flight Terrain Flight Approach Terrain Flight Navigation Emergency Procedures Radio Navigation Nonprecision Approach IMC Procedures/VHIRP Masking & Unmasking A/C Survivability Equipment Firing Position Ops Engage Tgt w/Hellfire Engage Tgt w/Arcs Engage Tgt w/AWS Evasive Maneuvers FARP Procedures Select Appropriate Weapon System ID Targets w/TADS	Instrument approach	
Management of unexpected events			
Statements and directives are clear, timely, relevant, complete, and verified			
Maintenance of mission situational awareness			
Decisions and actions communicated and acknowledged			
Supporting information and actions sought from crew			
Crewmember actions mutually cross-monitored			
Supporting information and actions offered by crew			
Advocacy and assertion practiced			
Crew-level after-action reviews accomplished			

Results

Results are presented with respect to differences in the crew condition independent variable across the dependent variable measures of crew performance. Data are reported from a differences perspective for each performance measure. All statistical analyses were completed using the Statistical Package for the Social Sciences Version 6.0 (SPSS for Windows; Norusis, 1993).

Behaviors (Basic Qualities)

Basic Quality ratings were made by IP evaluators during each data collection mission. On average, crew performance of the 13 crew coordination Basic Qualities produced mixed results with no statistically significant difference in IP evaluator ratings between battle-rostered and mixed crews. Table 9 compares Basic Quality item means between battle-rostered and mixed crew compositions. Mean ratings for every Basic Quality were at or above the acceptable level rating of 4. Battle-rostered crews performed slightly higher than mixed crews on nine Basic Qualities, whereas mixed crews performed slightly higher on four Basic Qualities.

Ratings were compared using a paired t-test to determine whether the Basic Quality performance differences were significant. In no case was the difference in performance of crew coordination Basic Qualities statistically significant. As summarized in Table 9, the mean rating for all 13 Basic Qualities was almost identical for battle-rostered and mixed crews.

Task Performance

IP evaluators graded crews on 25 selected ATM tasks for each data collection mission. The 25 tasks were selected for the following reasons:

1. They provided a common means for comparing battle-rostered and mixed crew evaluation missions.
2. They are crew coordination intensive.
3. They were explicitly presented in the evaluation scenarios.

The ATM task grades were converted for computer analysis so that S+ = 3, S = 2, S- = 1, and U = 0. Grades were compared using a paired t-test to determine whether task performance differences were significant.

Table 9

Behaviors (Basic Qualities) Comparisons Between Mean Rating Scores for Battle-Rostered and Mixed Crews

Crews (n=24)

	Basic Quality	Battle rostered	Mixed
1	Establish and maintain flight team leadership and crew climate	5.33	5.25
2	Pre-mission planning and rehearsal	5.17	5.33
3	Selection of appropriate decision-making techniques	4.46	4.58
4	Prioritize actions and distribute workload	4.63	4.54
5	Management of unexpected events	4.50	4.38
6	Statements and directives clear, timely, relevant, complete, and verified	4.75	4.83
7	Maintenance of mission situational awareness	4.21	4.04
8	Decisions and actions communicated and acknowledged	4.50	4.38
9	Supporting information and actions sought from crew	4.42	4.33
10	Crew member actions mutually cross-monitored	4.50	4.17
11	Supporting information and actions offered by crew	4.54	4.58
12	Advocacy and assertion practiced	4.54	4.38
13	Crew-level after-action reviews accomplished	5.04	4.88
	All 13 Basic Quality Ratings	4.66	4.59

On the average, crew performance of the 25 AH-64 ATM tasks produced mixed results with no statistically significant difference in IP evaluator grades between battle-rostered and mixed crews. Table 10 compares each of the 25 ATM task grades with the average

grade for all 25 tasks. The table also compares the overall grade for battle-rostered and mixed crew missions. Mean grades for every ATM task approached or exceeded the satisfactory level of performance. Battle-rostered crews performed slightly higher than mixed crews on 10 ATM tasks, whereas mixed crews performed slightly higher on 9 ATM tasks. Performance of six ATM tasks was the same for both crew compositions. In no case was the difference in performance of ATM tasks statistically significant. As summarized in Table 10, the mean grade for all 25 ATM tasks was almost identical for battle-rostered and mixed crews. The overall mission grade for both crew compositions was the same.

More precise information is available by linking ATM task performance and crew behaviors. When an ATM task was graded S- or U and the less than satisfactory grade involved crew coordination, IP evaluators noted the Basic Qualities contributing to the grade. Table 11 shows which ATM tasks were graded less than satisfactory and which Basic Qualities inhibited satisfactory performance for battle-rostered and mixed crews. Table entries and totals are the number of times an IP evaluator determined that the Basic Quality contributed to a less than satisfactory grade for the ATM task. Within each column, numbers to the left of the vertical line pertain to battle-rostered crews and numbers to the right are mixed crews.

Looking across the rows in Table 11, one can see that crews did not perform all ATM tasks satisfactorily for all missions. ATM tasks 1033 "Terrain Flight Mission Planning" and 2050 "Select Appropriate Weapon System" are exceptions in that they were not graded unsatisfactory due to crew coordination errors. The following is a list of the ATM tasks that caused the most problems, defined as those tasks with 10 or more Basic Quality negative notations:

1023	Fuel management procedures
1035	Terrain flight
1064	Terrain flight navigation
1081	Nonprecision approach
1119	Firing position operations
1140	Engage target with Hellfire
2008	Evasive maneuvers

Battle-rostered crews were graded unsatisfactory due to crew coordination errors more often than mixed crews on ATM tasks 1016 "Hover Power Check" and 1064 "Terrain Flight Navigation." Conversely, mixed crews received unsatisfactory grades due to crew coordination errors on ATM tasks 1023 "Fuel Management Procedures" and 1035 "Terrain Flight."

Table 10

Task Grade Comparisons Between Battle-Rostered and Mixed Crews

Crews (n=24)

	AH-64 ATM Task	Battle rostered	Mixed
1000	Crew Mission Briefing	2.29	2.38
1004	DA Form 5701-R (PC)	2.00	2.00
1007	Engine-start, run-up, hover, and before take-off checks	1.95	2.00
1016	Hover Power Check	1.88	2.04
1023	Fuel Management Procedures	1.96	1.67
1026	Doppler Navigation	1.79	1.92
1033	Terrain Flight Mission Planning	2.30	2.50
1034	Terrain Flight Takeoff	2.00	1.96
1035	Terrain Flight	1.92	1.58
1038	Terrain Flight Approach	2.00	1.83
1064	Terrain Flight Navigation	1.82	2.10
1068	Emergency Procedures	1.92	1.92
1076	Radio Navigation	1.92	1.75
1081	Nonprecision Approach	1.75	1.67
1083	IMC Procedures/VHIRP	2.08	2.00
1090	Masking & Unmasking	2.00	1.96
1095	A/C Survivability Equipment	2.13	1.96
1119	Firing Position Ops	1.79	1.88
1140	Engage Tgt w/Hellfire	1.92	1.96
1141	Engage Tgt w/ARCS	1.93	1.79
1142	Engage Tgt w/AWS	1.85	1.89
2008	Evasive Maneuvers	1.87	1.79
2043	FARP Procedures	1.94	2.00
2050	Select Appropriate Weapon System	2.00	2.04
2052	ID Targets w/TADS	1.92	1.88
	Average Grade for the 25 Tasks	1.96	1.95
	Overall Grade for Mission	1.58	1.50

Table 11
Less Than Satisfactory ATM Task Performance and Inhibiting Behaviors (Basic Qualities)
Crews (n=24)

Task	BQ1	BQ2	BQ3	BQ4	BQ5	BQ6	BQ7	BQ8	BQ9	BQ10	BQ11	BQ12	BQ13	Totals
1000	012	011	011			110			110			011		215
1004						110			112		011			213
1007	110						110							210
1016				210		210	110							510
1023				113			114			011				218
1026					110	110	314			011				415
1033														010
1034										111				111
1035				011			217	011		214	012			4115
1038			011	011		011	111			111	011			216
1064			110			110	511			211				912
1068	111					110	210			211				612
1076						011	111		012	011				115
1081	110	011				210	113		110	012		110		616
1083										011				011
1090			011								110			111
1095			011			110			110					211
1119	011		111	110		011	514			311	011			1019
1140	011					210	312				111			614
1141							111		011	110	012			214
1142							213			011				214
2008			210	011	011		312			011	011	011		517
2043							110							110
2050														010
2052					011		312			011				314
Totals	315	012	415	416	012	1213	36135	011	415	12118	219	112	010	78193

Note: Within each column, numbers to the left are battle-rotated crew results and numbers to the right are mixed crew results.

BQ1=Crew climate BQ2=Plan rehearsal BQ3=Decision techniques BQ4=Work load BQ5=Unexpected events BQ6=Positive comm BQ7=Situation awareness
BQ8=Comm/acknowledged BQ9=Info sought BQ10=Cross-monitor BQ11=Info offered BQ12=Advoc/alert BQ13=After Action Reviews

Looking down the columns in Table 11, it is apparent that all of the Basic Qualities except for BQ 13 "Crew-Level After-Action Reviews Accomplished" affected ATM task performance in varying degrees. The following is a list of the Basic Qualities that contributed the most to unsatisfactory ATM task performance, as defined as those Basic Qualities with 10 or more total entries for both battle-rostered and mixed crews:

BQ4 Prioritize actions and distribute workload
BQ6 Statements and directives clear, timely, relevant, complete, and verified
BQ7 Maintenance of mission situational awareness
BQ10 Crew member actions mutually cross-monitored
BQ11 Supporting information and actions offered by crew

Collectively, these five Basic Qualities accounted for 137 (80%) of the negative notations. Battle-rostered crews received more unsatisfactory ATM task grades due to crew coordination errors on two Basic Qualities, whereas mixed crews were graded unsatisfactory on ATM tasks more often than were battle-rostered crews on three of the five Basic Qualities. Table 12 focuses on these five Basic Qualities and compares the frequency of crew coordination errors associated with less than satisfactory ATM task performance for battle-rostered and mixed crews.

A statistical test of independent proportions was conducted to determine if the difference between battle-rostered and mixed crew frequencies was significant. Although the sample is small, the differences were statistically significant for Basic Quality 6 ($\underline{z} = 2.34$, $\underline{p} = 0.02$) and Basic Quality 11 ($\underline{z} = -2.12$, $\underline{p} = 0.03$).

Mission Performance

Aircrews were given attack helicopter tactical missions to perform in the AH64CMS. Data were collected from four evaluation missions to determine if mission performance was affected by whether the crews were battle rostered or mixed. Mission performance data were analyzed in the following categories: navigation, weapons employment, threat, unexpected events, and instrument approach. Performance measures that evaluated terrain flight navigation, weapons systems employment, and threat avoidance and evasion were recorded during all four evaluation missions. Performance measures that evaluated unexpected events, including aircraft emergencies and minor malfunctions, and instrument recovery were recorded during two or more of the evaluation missions.

Table 12

Crew Coordination Errors Associated With Less Than Satisfactory ATM Task Performance

Crews (n=24)

	Basic Quality	Battle rostered		Mixed
4	Prioritize actions and distribute workload	4		6
6	Statements and directives clear, timely, relevant, complete, and verified	12	*	3
7	Maintenance of mission situational awareness	36		35
10	Crew member actions mutually cross-monitored	12		18
11	Supporting information and actions offered by crew	2	*	9

* $p \leq .05$ based on 600 rating opportunities (24 crews x 25 ATM tasks).

Navigation. This performance measure evaluates the crew's ability to remain within altitude and course limitations as well as to avoid inadvertent obstacle strikes and collisions with the ground. The measure also evaluates the crew's ability to meet timed arrival requirements at designated checkpoints.

Crew terrain flight navigation performance produced mixed results with no statistically significant difference between battle-rostered and mixed crews. Overall, battle-rostered crews had fewer altitude and course deviations and incurred fewer detrimental outcomes than did mixed crews. From a crew perspective, 67% of battle-rostered crews and 50% of mixed crews completed their missions without any detrimental outcomes. A total of 18 crews performed 36 missions, which included timed arrival requirements at a designated checkpoint. As shown in Table 13, 75% of all crews met their arrival time requirement within 2 minutes with little variation between battle-rostered and mixed crews.

Weapons employment. This performance measure evaluates the crew's ability to accurately acquire, identify, and engage targets.

Table 13

Comparison of Navigation Arrival Times

Crews (n=18)

Arrival time	Battle rostered	Mixed
≤1 Minute	5	7
>1 ≤2 Minutes	8	7
>2 ≤3 Minutes	1	2
>3 Minutes	4	2

Crew weapons systems employment performance produced mixed results, with battle-rostered crews hitting and killing more targets than did mixed crews. As shown in Table 14, battle-rostered crews acquired more of the total available targets than did mixed crews, whereas the mixed crews engaged more of the targets they acquired than did battle-rostered crews. Battle-rostered crews hit and killed more of the targets engaged (104 of 147) than did mixed crews (82 of 139). A test of proportions was used to determine whether the mission performance differences in weapons employment were significant. The difference in the number of targets hit and killed, including targets hit and killed by autonomous missile engagements, between battle-rostered and mixed crews was statistically significant ($z = 2.08$, $p = 0.04$). However, one battle-rostered crew improperly identified a friendly target and fired on it.

When each weapon system was analyzed separately, battle-rostered crews hit and killed more targets with missiles than did mixed crews, including autonomous engagements where the difference in hits and kills (57 of 65 versus 46 of 66) was found to be statistically significant ($z = 2.51$, $p = 0.02$). The small difference in the proportion of targets hit and killed with rocket and gun engagements by battle-rostered and mixed crews was not statistically significant. One mixed crew accounted for almost half of the rocket hits and kills. The sum of targets engaged by each weapon system exceeds the total number of targets engaged

Table 14

Comparison of Weapons Systems Employment Measures

Crews (n=24)

Measure	Battle rostered		Mixed
Number of targets acquired of available targets	178/232		165/232
Number of targets engaged of targets acquired	147/178		139/165
Number of targets hit and killed of targets engaged	104/147	*	82/139
Number of targets hit and killed of autonomous and remote missile engagements	75/80		60/83
Number of targets hit and killed of autonomous missile engagements	57/65	*	46/66
Number of targets hit and killed of rocket engagements	18/47		13/33
Number of targets hit and killed of gun engagements	11/55		9/34

* $p \leq .05$ Test of proportions.

since several crews engaged targets with multiple weapon systems.

Threat. This performance measure involves the crew's ability to avoid and, if detected, successfully evade threat weapon systems. It also describes certain detrimental outcomes resulting from threat detection; that is, became misoriented, hit by a threat system, or crashed. Threat systems used in all four scenarios were representative of Soviet-equipped motorized and armored units.

Crew performance regarding threat avoidance and evasion produced mixed results with no statistically significant difference between battle-rostered and mixed crews. As shown in Table 15, mixed crews had fewer radar warnings, fewer detrimental outcomes,

Table 15

Comparison of Threat Avoidance and Evasion Measures

Crews (n=24)

Measure	Battle rostered	Mixed
Number of threat radar warnings	34	31
Number of detrimental outcomes	14	11
Average duration of radar warnings (seconds)	34.7	21.2
Number of crews completing missions with no radar warnings	8	5

and an overall shorter average duration of radar warnings than did battle-rostered crews. Three battle-rostered crews and three mixed crews incurred more than one detrimental outcome during a mission.

Because nonradar-controlled threat systems, that is, T80 tanks, BMP-2 personnel carriers, and MI-24F helicopters, were included in each scenario, several crews were able to avoid radar warnings but still incurred detrimental outcomes from other threat systems. Battle-rostered crews had better success at avoiding radar-controlled threat systems and were more successful at avoiding all threat systems.

As shown in Table 16, almost 70% of all the crews had average warning times less than 30 seconds with more mixed crews than battle-rostered crews included in this group. Several crews remained exposed to a radar-controlled system because they were aware that they were outside of the weapon system's effective range. As a result, these crews incurred unusually lengthy warning times, which adversely affected overall average warning time. For example, 3 of 4 battle-rostered crews had average times exceeding 100 seconds. Warning times were not recorded for one battle-rostered and one mixed crew.

Unexpected events. This performance measure evaluates the crew's ability to work in concert while coping with emergencies, malfunctions, and inadvertent entry into instrument meteorological conditions (IMC). Crews coped with a minor malfunction and an inadvertent entry into IMC during two missions, while the other

Table 16

Comparison of Average Radar Warning Times

Crews (n=23)

Average radar warning time	Battle rostered	Mixed
≤15 Seconds	8	10
>15 ≤30 Seconds	5	9
>30 ≤60 Seconds	6	3
>60 Seconds	4	1

two missions contained a minor malfunction and an aircraft emergency. Crew performance during unexpected event situations produced mixed results with no statistically significant difference between battle-rostered and mixed crews.

The crew's ability to cope with aircraft emergencies was measured in the second and fourth evaluation missions. During the second mission, 12 crews experienced a loss of engine oil and subsequent failure of the engine while returning to the FARP. Every crew correctly diagnosed the emergency and properly performed the required emergency procedures. One battle-rostered crew crashed performing the running landing following this emergency. While returning to the FARP during the fourth mission, 12 crews had an engine chip detector illuminate followed 15 seconds later by a complete engine failure. All but one battle-rostered crew correctly diagnosed the emergency and properly performed the required emergency procedures. One mixed crew crashed performing the running landing following this emergency.

Crew performance during system malfunctions was measured in all four missions. During the first and third missions, crews experienced minor malfunctions associated with the electrical and hydraulic systems, respectively, en route to the FARP. All 24 crews correctly diagnosed the malfunctions. One battle-rostered and one mixed crew delayed initiating the emergency procedures until after landing, and one battle-rostered crew crashed performing the landing in the FARP.

During the second and fourth missions, crews experienced malfunctions associated with the communications and fuel systems. While occupying a battle position during the second mission, both FM radio circuit breakers popped, temporarily disabling both FM radios. While en route to the second battle position during the fourth mission, crews experienced a slow fuel leak resulting in an incremental loss of 500 lbs of fuel. No warnings are associated with either of these malfunctions. The crews were required to detect these malfunctions through situational awareness and cross-checks of aircraft systems. As shown in Table 17, half of all the crews were successful in detecting these more subtle malfunctions in less than seven minutes with more mixed crews than battle-rostered crews included in this group.

Table 17

Comparison of Malfunction Detection Times

Crews (n=12)

Average time to detect malfunction	Battle rostered	Mixed
≤2 Minutes	2	3
>2 ≤7 Minutes	3	4
>7 ≤20 Minutes	3	2
>20 Minutes	4	3

Inadvertent entry into IMC was measured during the first and third missions. Crews experienced deteriorating weather conditions on the flight back to the FARP, which resulted in a loss of visual reference while terrain flying. Every crew except one mixed crew successfully completed the vertical helicopter instrument recovery procedure (VHIRP), transitioning from visual to instrument meteorological conditions.

Instrument approach. This performance measure evaluates the crew's ability to plan and execute a non-precision instrument recovery procedure after inadvertently entering IMC. This measure was recorded for 12 battle-rostered and 12 mixed crews during the first and third missions. Crew instrument approach performance produced mixed results with no statistically significant difference between battle-rostered and mixed crews.

Three dimensions of this measure were observed for each crew: planning the approach, timing the inbound leg, and the outcome of the approach. Table 18 shows the results for each dimension by battle-rostered and mixed crews.

Table 18

Comparison of Instrument Approach Performance

Crews (n=12)

Measure	Battle rostered	Mixed
Planning the approach		
Superior	1	2
Good	4	4
Poor	7	6
Unsatisfactory	0	0
Timing the inbound leg	10	6
Successful outcome of the approach	10	9

Most crews received a poor rating for approach planning with little variation between battle-rostered and mixed crews. More battle-rostered crews than mixed crews properly timed their approaches. Most crews successfully completed the instrument approach with little variation between battle-rostered and mixed crews. All of the crews with superior ratings for approach planning completed all requirements of the approach successfully; that is, the crew properly planned, timed, and executed the approach.

Participant Exit Interviews

Crew members and IP evaluators were interviewed after all of the data collection missions were completed.

Self-ratings. Anecdotal evidence from aviation accident investigations and informal comments made by Army aviators during

this and previous research suggested a performance downside to battle rostering. Specifically, it was suggested that repeated flights with the same crew member builds confidence, which can lead to overconfidence and complacency. It was also suggested that crew members were more formal and overt in carrying out procedures and crew coordination actions when flying with other than their battle-rostered crew. The crew member self-rating questionnaire was designed to provide a subjective measure of these aspects of crew coordination to supplement the behaviors (Basic Qualities) and task performance data collected earlier. Table 19 shows the results of crew member self-ratings on three aspects of crew coordination performance in battle-rostered and mixed crews.

Crew member self-ratings produced mixed results with statistically significant differences between battle-rostered and mixed crews. A paired t-test revealed that crew members rated themselves overall more effective (5.9 versus 5.4) when operating in a battle-rostered crew than in a mixed crew configuration (t = 3.69, df = 22, p = .001). They rated their workload difficulty in a battle-rostered crew as easier (5.6 versus 4.9) than in a mixed crew (t = 4.18, df = 22, p = .000). These same crew members rated their crew coordination style as more implicit (4.2 versus 4.9) in a battle-rostered crew than when in a mixed crew (t = -3.07, df = 22, p = .006).

Crew members completing the self-rating questionnaire represented 22 of the 24 battle-rostered crews and 19 of the 24 mixed crews participating in the experiment. Both battle-rostered and mixed crews rated themselves higher than their actual performance as measured by IP evaluators. Table 20 compares crew self-ratings with IP evaluator ratings of the 13 behaviors (Basic Qualities). The amount that crews overrated their performance is an estimate of overconfidence. Battle-rostered crews were 50% more overconfident in their performance than mixed crews.

Crew member self-ratings of crew coordination style were used to determine the crew coordination style of the crew; that is, implicit or explicit style. When either or both crew members rated their overall crew coordination performance as implicit, the crew was identified as having operated using an implicit crew coordination style. Table 21 shows a comparison of implicit coordination styles between battle-rostered and mixed crews. Implicit crew coordination style was associated more frequently (64% versus 42%) with battle-rostered crews than with mixed crews.

Table 19

Crew Member Self-ratings of Crew Coordination Performance

Crew members (n=23)

Basic Quality	Effectiveness			Difficulty			Style		
	Battle rostered	Mixed	Battle rostered	Battle rostered	Mixed	Battle rostered	Mixed		
	1=Less, 7=More			1=Difficult, 7=Easy			1=Implicit, 7=Explicit		
1. Crew Climate	6.00	**	5.35	5.91	**	5.13	4.04	**	5.13
2. Plan Rehearse	6.30		5.96	5.91	**	5.13	4.30	**	5.26
3. Decision Techniques	5.70	*	5.26	5.52	**	4.83	4.00	**	4.74
4. Workload	6.09	*	5.52	5.65	**	4.70	3.74	**	4.74
5. Unexpected Events	5.78	**	5.09	5.09	**	4.48	4.39		4.83
6. Information Transfer	5.83	*	5.30	5.48	**	4.70	4.30	**	5.09
7. Situational Awareness	5.78	**	5.30	5.13	**	4.52	4.22	*	4.78
8. Communicate Acknowledge	4.78		5.57	5.61	**	4.91	4.13	*	4.91
9. Information Sought	5.78	*	5.09	5.52	**	4.65	4.22	*	4.91
10. Cross Monitor	5.73		5.27	5.46	**	4.55	3.36	*	4.41
11. Information Offered	6.09	**	5.39	5.78	**	4.83	4.30	*	5.04
12. Advocacy/Assertion	6.04	*	5.35	5.61	*	4.83	4.26		4.83
13. After Action Review	5.96		5.61	6.35	*	6.00	5.39		5.52
Mean Basic Quality Score	5.91	**	5.39	5.62	**	4.87	4.21	**	4.94

*p ≤ .05 **p ≤ .01 Paired t-test.

*p < .05 **p < .01 Paired t-test.

Table 20

Crew Confidence

Crew members (n=23)

Rater	Battle rostered	Mixed
Crew self-ratings of 13 Basic Qualities	5.9	5.4
IP evaluator ratings of 13 Basic Qualities	4.7	4.6
Overconfidence factor	1.2	0.8

Table 21

Implicit Coordination Style

Crew members (n=23)

	Battle rostered	Mixed
Number of crews rated	22	19
Number of crews with implicit coordination style	14	8
Percent implicit style	64%	42%

Open-ended questions. In Appendix B, the open-ended exit interview questions are stated, a summary of the responses is given, the detailed responses are provided, and the project staff's reaction to each set of comments is stated. Many of the experiment conclusions and recommendations were generated or reinforced during the exit interviews. The reader is encouraged to closely examine Appendix B. Following is a summary of crew member and IP evaluator comments:

1. Battle-rostered crews tended to abbreviate mission planning with comments such as, "Like we always do." When pressed for details, crew members did not have a common understanding. (IP Evaluator)

2. Performance depends more on the level of crew experience than whether or not they are battle rostered. (Crew member)

3. There is a better mission flow with a battle-rostered crew member. [Others disagreed.] I am more deliberate in a mixed crew. I didn't "shoot from the hip" as I did with my battle-rostered crew member. (Crew member)

4. Quicker detection of error chains with battle-rostered crews was purely a perception on the part of the crews. In reality, breaking error chains depends on crew member assertiveness. (IP Evaluator)

5. Some complacency is found with battle rostering. Flying with other crews guards against complacency. You learn things from different aviators. (Crew member)

6. Confidence can lead to overconfidence and complacency. The one time your battle-rostered buddy doesn't perform as expected comes as a big surprise. (Crew member)

7. Battle-rostered crews had well established crew climates and were familiar with each other. (IP Evaluator)

8. There was more cross-monitoring and prompting (providing information) with the mixed crew. More information is passed with a mixed crew. (Crew member)

9. Coordination was better in the mixed crew, even though we performed adequately in both cases. (Crew member)

10. Experience has a big influence on your confidence level and how you operate as a crew member. Confidence can lead to overconfidence and complacency. (Crew member)

11. Battle-rostered crews were more informal, complacent, and overlooked things. Mixed crews were more formal, attentive, and did not overlook things as much. (IP Evaluator)

12. Implied communication and implied tasks were more prevalent with battle-rostered crews. (IP Evaluator)

Discussion

This experiment provided little evidence that battle rostering contributes additional significant improvements to mission performance or flight safety as compared to the use of crew coordination training alone. In fact, experimental evidence suggests that battle rostering induces a greater degree of overconfidence, which is a possible contributor to aviation accidents. The experiment applied the crew coordination ETP pre- and post-training method and measures to examine the marginal contributions of battle rostering. Interpretations made by data collectors and project staff during the conduct of the experiment are incorporated in this discussion.

The discussion of the results of this experiment is organized into three sections. The first section examines mission performance and addresses the crew behavior, task performance, and mission performance hypotheses. The second and third sections discuss results relevant to flight safety and familiarity effects, respectively.

Mission Performance

The overall effect of crew composition on crew coordination behavior and task performance was insignificant. Battle-rostered and mixed crew ratings on behaviors (Basic Qualities) and grades on ATM tasks offered few insights into performance differences except for the area of less than satisfactory task performance. The analysis of crew coordination deficiencies associated with less than satisfactory task performance suggested that crew composition may affect crew coordination behaviors in the cockpit. A statistically significant difference was found between battle-rostered and mixed crews for two Basic Qualities.

Battle-rostered crews received more unsatisfactory task grades due to errors in performing Basic Quality 6 "Statements and Directives Clear, Timely, Relevant, Complete, and Verified." The finding suggests that battle-rostered crews tended to revert to an implicit style of crew coordination, typically observed before crew coordination training, more often than mixed crews did. Crew composition also affected how mixed crews coordinated in the cockpit. Mixed crews were graded unsatisfactory more often than battle-rostered crews for errors in Basic Quality 11 "Supporting Information and Actions Offered by Crew." Speculation by IP evaluators and project staff is that crew members in mixed crews tended to concentrate more on their individual duties and

responsibilities rather than on supporting their fellow crew member with information and assistance.

Unsatisfactory performance of specific tasks due to crew coordination errors can also be attributed to crew composition effects. The tendency of battle-rostered crews to coordinate implicitly contributed to their less than satisfactory performance of Task 1016 "Hover Power Check" and Task 1064 "Terrain Flight Navigation." Both of these tasks require explicit call out and response items to achieve the performance standard. Less than satisfactory performance of Task 1035 "Terrain Flight" by mixed crews is believed to be partially attributable to failure to provide information and assistance, an effect of crew composition. Including information in crew coordination training on the nature of these tendencies when operating in a battle-rostered or mixed crew is a possible remedy for less than satisfactory task performance.

In comparing battle-rostered versus mixed crews across the five areas of mission performance measured in the experiment, only one difference was found to be statistically significant. Battle-rostered crews achieved more missile kills per target engaged. Engaging targets with missiles from the AH-64 requires precise target acquisition and weapon systems settings, adjustments, and sequencing actions between the pilot and CPG. Familiarity with the other crew member's experience and preferred techniques provides a time advantage in anticipating and offering information and assistance. This advantage can result in fewer lost targets and lost missiles. These results indicate that battle rostering aircrews has a potential positive effect on gunnery performance.

Flight Safety

Crew composition had no significant effect on flight safety. Crew flight safety was evaluated using the results from the experiment's safety intensive task and mission performance measures.

Task results were drawn from crew performance of ATM tasks most frequently cited in aircraft accident reports. These tasks included terrain flight, firing position operations, evasive maneuvers, emergency procedures, and execution of a nonprecision instrument approach. Remaining clear of obstacles and the ground while performing these tasks requires crew members to interact and coordinate actions. There was no significant difference between battle-rostered and mixed crew performance of flight safety tasks.

Three mission performance measurement areas provided flight safety results in terms of detrimental outcomes. Detrimental

outcomes for the terrain flight mission performance measure included obstacle strikes and collision with the ground. The additional measures of misorientation and recovery fire were used to evaluate the threat evasion mission. Unexpected events performance measures provided additional collision with the ground results. There was no significant difference between battle-rostered and mixed crew flight safety mission performance.

In addition to task and mission performance measures, crew flight safety was evaluated from an error chain perspective. IP evaluators, CMS operators, and project staff recorded instances of a series of errors or events with potential to jeopardize mission effectiveness or flight safety. For example, a crew recovering from evading a threat system failed to recognize an engine governor malfunction, failed to maintain minimum safe flight parameters, and crashed while occupying a new position. Error chain results included crews that interacted to break error chains early before suffering adverse mission or safety consequences. Both battle-rostered and mixed crews demonstrated similar error chains.

Familiarity Effects

The familiarity effect results of this experiment suggest that battle rostering crews has a potential adverse effect on mission performance and flight safety. Results from the crew member self-rating questionnaire support the hypothesis that crew overconfidence and complacency are significantly higher with battle-rostered crews.

The finding that crew members rate themselves 50% more confident when flying in their battle-rostered crew than in a mixed crew has negative implications. Overconfidence is suspected as a possible contributor to aviation accidents and crew complacency. Battle-rostered crews rated their workload as easier and their crew coordination style as more implicit than mixed crews did. This last finding tends to support the perception that battle rostering fosters implicitness, which can lead to informality and complacency. Crew member perceptions that they detected and broke more error chains quicker when in a battle-rostered crew were not supported by IP evaluator observations.

Including information in crew coordination training on the negative familiarity effects of battle rostering is a possible hedge against mission performance and flight safety risk.

Conclusions and Recommendations

The crew composition experiment was successful in evaluating the interactive effects of crew coordination training and battle

rostering on AH-64 attack helicopter battalion aircrews. As shown in Table 22, crew coordination training administered to battle-rostered crews in June 1993 significantly improved crew performance in all measurement areas. This experiment to evaluate the effects of battle rostering on crew performance extended the research using the same population of battle-rostered crews now fully trained in the Army's crew coordination principles. Both crew coordination behaviors (Basic Qualities) and task performance remained relatively stable after unit aviators received the Aircrew Coordination Exportable Training Package (Pawlik et al., 1992). The experiment results supported one of the five research hypotheses. Preliminary results provided sufficient evidence to support a policy decision that makes battle rostering of aircrews optional rather than mandatory. The policy announcement emphasized the risks associated with battle rostering as identified in the experiment.

Conclusions

The principal research issue was: Does battle rostering produce observable improvements in mission performance and flight safety? The overall conclusion from the experiment was, that while some aviators perceive battle rostering to improve crew performance, minimal experimental evidence shows meaningful improvements in mission performance or flight safety. In fact, the contributions of battle rostering to crew mission effectiveness and flight safety were largely offset by unmet expectations and drawbacks. Objective data and participant comments concluded that the principal contributions of battle rostering were as follows:

1. Improved weapons employment mission performance (Table 14), and
2. Increased familiarization and confidence within crews (Table 19).

IP evaluator observations and objective mission data did not confirm the intuitive expectations of battle rostering. Battle rostering provided:

1. No improvement in overall crew coordination performance (Table 9),
2. No improvement in overall ATM task performance (Table 10), and
3. No insurance of reduced risk (Tables 9 and 18).

Table 22

Comparison of Crew Coordination Training and Crew Composition Experiment Performance

Performance Measures	Crew Coordination Training, Jun 93			Crew Composition Experiment, Oct 93	
	All crews battle rostered (n=8)			All crew coordination trained (n=24)	
	Before training	After training		Battle rostered	Mixed
Behaviors	4.50	4.88		4.66	4.59
Task performance	1.50	1.97		1.96	1.95
Mission performance	Significant improvement in 3 of 5 areas			No difference except weapons	
-Navigation	Significant improvement			No difference	
-Weapons	Significant improvement			Significant difference	
-Threat	No significant improvement			No difference	
-Emergency	No significant improvement			No difference	
-Instrument	Significant improvement			No difference	

Both objective and subjective data collected during the experiment identified the following operational and administrative drawbacks associated with battle rostering:

1. Fostered overconfidence (Table 20),
2. Fostered informal and nonstandard procedures (IP Evaluator Open-ended Questionnaire, item 7), and
3. Fostered implicit coordination behaviors (Table 21).

Summary conclusions of this study support one of the five research hypotheses.

1. *Crew coordination behavior will be significantly improved through a combination of crew coordination training and battle rostering, as compared to the use of crew coordination training alone.* Crew performance of the 13 crew coordination behaviors (Basic Qualities) produced mixed results with no statistically significant difference between battle-rostered and mixed crews. Results from task performance and crew member self-ratings offered sufficient evidence to suggest that battle-rostered crews tend to revert to an implicit style of crew coordination more often than mixed crews do.

2. *Crew flight task performance will be significantly improved through a combination of crew coordination training and battle rostering, as compared to the use of crew coordination training alone.* Crew performance of the 25 ATM tasks produced mixed results with no statistically significant difference between battle-rostered and mixed crews. The implicit crew coordination tendency demonstrated by battle-rostered crews produced an adverse effect on their performance of some ATM tasks.

3. *Mission performance will be significantly improved through a combination of crew coordination training and battle rostering, as compared to the use of crew coordination training alone.* While there were small but statistically significant differences in the area of weapons employment, crew performance of the five areas of mission performance produced mixed results with no other statistically significant difference. Battle rostering crews has a potential positive effect on gunnery performance.

4. *Flight safety will be improved through a combination of crew coordination training and battle rostering, as compared to the use of crew coordination training alone.* Crew performance of the three flight safety intensive mission performance areas and the safety-related ATM tasks produced mixed results with no

statistically significant difference between battle-rostered and mixed crews. Both crew composition types demonstrated similar error chains.

5. *Crew overconfidence and complacency will be significantly higher with battle-rostered crews, as compared to non-battle rostered crews.* Battle-rostered crews overrated their performance 50% more than did mixed crews. Crew members and IP evaluators commented that overconfidence can lead to complacency. Crew members rated their crew coordination style as more implicit when in a battle-rostered crew than when in a mixed crew. Implicit crew coordination coupled with overconfidence is a potentially detrimental combination with adverse effects on mission performance and flight safety.

Recommendations

The principal operational issue was, "Should Army policy require commanders to battle roster aircrews?" The Army's initial strategy was to achieve crew coordination by simultaneously mandating battle-rostered crews and conducting crew coordination training. The results of the research program lead to the conclusion that the crew coordination training component of that strategy is achieving the objective. The mechanism for improving crew coordination, the Aircrew Coordination Exportable Training Package, (Pawlik et al., 1992) is already being fielded by the USAAVNC's Aviation Training Brigade. The research conclusions further suggest that crew coordination training and evaluation does not have to be tied to battle-rostered crews.

Following is a two-part list of recommendations. The first set of recommendations is implementing actions for this research to improve mission effectiveness and flight safety. The second set of recommendations is for conducting research to address unresolved crew and team coordination issues.

Recommendations - Implement current research.

1. Document the requirement that all crew members (rated and nonrated) must receive crew coordination training. Because standardized training was found to be the preferred solution to improve crew coordination, it is now more important than ever to make sure the training is fully implemented. The requirement to complete the Army's Aircrew Coordination Training Program (Pawlik et al., 1992) should be promulgated in key policy documents, for example, AR 95-1 (Department of the Army, 1990) and TC 1-210 (Department of the Army, 1992b). Emphasize that crew coordination training helps to offset any negative habits introduced by repeated flights with the same crew. Crew familiarity effects can be

mitigated by emphasizing the importance of explicit crew coordination when flying in a battle-rostered crew and by emphasizing the importance of supporting other crew members when flying in a mixed crew.

2. Allow unit commanders to battle roster crews as a risk management tool without the administrative requirement for mandatory crew readiness level progression. Results of the experiment suggest that commanders may reduce risk and enhance areas of mission performance by battle rostering crews for short periods of time for specific missions, for example, gunnery. Commanders should be cautioned that making permanent crew assignments can potentially jeopardize both mission performance and flight safety. Requiring that all crew members complete crew coordination training before being selected and/or designated as part of a crew, eliminates the need to establish and manage levels of crew readiness. Crew designation and continuity should be based on the pilot in command (PC) rather than on the full complement of individual crew members. Once aviators successfully complete crew coordination training and are certified by the unit commander, they should be ready to serve as part of any crew.

3. Specify that crew coordination refresher training be accomplished on an annual basis within each unit. Tendencies revealed during the experiment for crew members to revert to an implicit crew coordination style, and individual rather than crew mission orientation make it important to develop and implement crew coordination refresher training. As a minimum, refresher training should include an update of recent crew coordination related accidents, a review of observed crew coordination performance in the unit, and a training mission in the simulator or aircraft. It is especially important to reinforce the need for explicit crew coordination.

4. Incorporate crew coordination Basic Qualities from the Aircrew Coordination Exportable Training Package (Pawlik et al., 1992) into each ATM for individual Annual Proficiency and Readiness Test (APART) evaluations. Individuals and crews pay particular attention to the areas of their performance that are formally evaluated. As shown in the experiment, crew coordination evaluations do not have to be tied to battle-rostered crews. Unit IPs who have completed the Crew Coordination Instructor Course are fully trained to rate crew coordination performance using either the modified ATM grade slip (Pawlik et al., 1992) or the Aircrew Coordination Evaluation (ACE) Checklist (Grubb, Simon, & Zeller, 1992).

Recommendations - Research unresolved issues.

1. Conduct additional research to address the crew composition effects on utility, cargo, and observation crews operating under low visibility conditions using individual night vision devices (NVD). Experiment results are based on crew performance in the AH-64 attack helicopter with its fully integrated target acquisition designation sight and pilot night vision system. Aircraft without shared access to sensor systems and/or symbology demand more explicit crew coordination because of limited fields of view and assigned scan sectors. It is not known if battle rostering improves the performance of crew coordination-trained cargo and utility crews; for example, accurate and safe navigation at night. Both the CH-47 and UH-60 visual flight simulators are capable of video recording night missions under NVD conditions.

2. Pursue additional research to understand the effects of complacency and time intervals between flights by the same crew on performance and safety. Operational mission requirements limit the availability of aircrews to compressed periods of research data collection. In this experiment, crews completed all 48 evaluation missions in 14 days. It is not known to what extent temporal factors affect battle rostering-fostered complacency nor is it known how many flights together it takes as a crew before overconfidence becomes a factor. A longitudinal study of crew coordination-trained crew members is needed.

3. Develop crew selection methods and tools to assist units in assigning crew members for training and combat missions. Participants in the experiment indicated the need to provide units with improved crew selection capabilities. Commanders have wide latitude in distributing risk and crew member experience. Reliable instruments are available to measure personality traits, individual skills, and crew coordination skills as inputs to a crew selection automated method. Technology is available to develop advanced crew selection methods software for use on microcomputers. An automated crew selection tool should be developed to help units simultaneously manage risk and provide high levels of mission accomplishment by using all available information to select crews.

4. Extend crew coordination training to a non-aviation crew-served weapon system that battle rosters crews (for example, M1 tank). Crew coordination research has focused primarily on the aviation component of the Army's combined arms team. Increasingly complex ground systems exhibit crew error patterns similar to aviation, resulting in degraded mission performance and safety mishaps, especially during night operations. It would be useful to

apply the aviation-based crew coordination concepts to a ground combat system and conduct similar research to assess the difference in mission performance and safety.

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Appendix A

Crew Member Self-rating Questionnaire (Extract)

Crew Coordination Research Crew Member Exit Questionnaire

Introduction

This questionnaire is used to record your perception as a crew member during the AH-64 Combat Mission Simulator sessions conducted during the previous few weeks by USAAVNC and USARI. You will be asked to think about each of the important dimensions of crew coordination addressed in previous training. For each dimension, you will be asked to give us your subjective ratings of effectiveness, difficulty, and style used during your "battle-rostered" versus "mixed crew" missions. These ratings are described below:

Effectiveness This rating reflects your own view as to how well you performed this aspect of crew coordination as a crew. The rating is made on a 7-point scale, ranging from a low of 1 (Very Poor) to a high of 7 (Superior).

Difficulty This rating reflects your own view as to the level of difficulty you encountered in performing this aspect of crew coordination. Again, the rating is made on a 7-point scale, ranging from a low of 1 (Very Easy) to a high of 7 (Very Difficult).

Style This rating reflects your own view as to the manner in which you performed this aspect of crew coordination. In this case, style refers to how explicitly were the crew coordination actions carried out during the missions. The rating is made on a 7-point scale ranging from a value of 1 (Consistently Explicit) to the opposite value of 7 (Consistently Implicit). Explicit and implicit styles are further described as follows:

Explicit This aspect of crew coordination was conducted in an open and observable manner, using positive statements and acknowledgements. Nothing was taken for granted regarding the other crew member's understanding of required actions or statements. Crew coordination was accomplished "by the book" in accordance with previous training.

Implicit This aspect of crew coordination was conducted in a nonobservable and subconscious manner, without the use of positive statements and acknowledgements. The other crew member's understanding of required actions or statements was assumed to be consistent with yours. Crew coordination was accomplished subconsciously, based upon a sense of mutual anticipation that develops through previous flight experiences.

RATING FORM

Cross-indexing code: _____ (Last 4 digits of SSN)

1. Establish and maintain flight team leadership and crew climate

Effectiveness in Performing This Aspect of Crew Coordination

Battle Rostered	<input type="checkbox"/> Very Poor	<input type="checkbox"/> Poor	<input type="checkbox"/> Marginal	<input type="checkbox"/> Acceptable	<input type="checkbox"/> Good	<input type="checkbox"/> Very Good	<input type="checkbox"/> Superior
Mixed Crew	<input type="checkbox"/> Very Poor	<input type="checkbox"/> Poor	<input type="checkbox"/> Marginal	<input type="checkbox"/> Acceptable	<input type="checkbox"/> Good	<input type="checkbox"/> Very Good	<input type="checkbox"/> Superior

Difficulty in Performing This Aspect of Crew Coordination

Battle Rostered	<input type="checkbox"/> Very Easy	<input type="checkbox"/> Easy	<input type="checkbox"/> Somewhat Easy	<input type="checkbox"/> Neutral	<input type="checkbox"/> Somewhat Difficult	<input type="checkbox"/> Difficult	<input type="checkbox"/> Very Difficult
Mixed Crew	<input type="checkbox"/> Very Easy	<input type="checkbox"/> Easy	<input type="checkbox"/> Somewhat Easy	<input type="checkbox"/> Neutral	<input type="checkbox"/> Somewhat Difficult	<input type="checkbox"/> Difficult	<input type="checkbox"/> Very Difficult

Style of Performing This Aspect of Crew Coordination

Battle Rostered	<input type="checkbox"/> Consistently Explicit	<input type="checkbox"/> Mostly Explicit	<input type="checkbox"/> Somewhat Explicit	<input type="checkbox"/> Mixed	<input type="checkbox"/> Somewhat Implicit	<input type="checkbox"/> Mostly Implicit	<input type="checkbox"/> Consistently Implicit
Mixed Crew	<input type="checkbox"/> Consistently Explicit	<input type="checkbox"/> Mostly Explicit	<input type="checkbox"/> Somewhat Explicit	<input type="checkbox"/> Mixed	<input type="checkbox"/> Somewhat Implicit	<input type="checkbox"/> Mostly Implicit	<input type="checkbox"/> Consistently Implicit

2. Premission planning and rehearsal accomplished

Effectiveness in Performing This Aspect of Crew Coordination

Battle Rostered	<input type="checkbox"/> Very Poor	<input type="checkbox"/> Poor	<input type="checkbox"/> Marginal	<input type="checkbox"/> Acceptable	<input type="checkbox"/> Good	<input type="checkbox"/> Very Good	<input type="checkbox"/> Superior
Mixed Crew	<input type="checkbox"/> Very Poor	<input type="checkbox"/> Poor	<input type="checkbox"/> Marginal	<input type="checkbox"/> Acceptable	<input type="checkbox"/> Good	<input type="checkbox"/> Very Good	<input type="checkbox"/> Superior

Difficulty in Performing This Aspect of Crew Coordination

Battle Rostered	<input type="checkbox"/> Very Easy	<input type="checkbox"/> Easy	<input type="checkbox"/> Somewhat Easy	<input type="checkbox"/> Neutral	<input type="checkbox"/> Somewhat Difficult	<input type="checkbox"/> Difficult	<input type="checkbox"/> Very Difficult
Mixed Crew	<input type="checkbox"/> Very Easy	<input type="checkbox"/> Easy	<input type="checkbox"/> Somewhat Easy	<input type="checkbox"/> Neutral	<input type="checkbox"/> Somewhat Difficult	<input type="checkbox"/> Difficult	<input type="checkbox"/> Very Difficult

Style of Performing This Aspect of Crew Coordination

Battle Rostered	<input type="checkbox"/> Consistently Explicit	<input type="checkbox"/> Mostly Explicit	<input type="checkbox"/> Somewhat Explicit	<input type="checkbox"/> Mixed	<input type="checkbox"/> Somewhat Implicit	<input type="checkbox"/> Mostly Implicit	<input type="checkbox"/> Consistently Implicit
Mixed Crew	<input type="checkbox"/> Consistently Explicit	<input type="checkbox"/> Mostly Explicit	<input type="checkbox"/> Somewhat Explicit	<input type="checkbox"/> Mixed	<input type="checkbox"/> Somewhat Implicit	<input type="checkbox"/> Mostly Implicit	<input type="checkbox"/> Consistently Implicit

Appendix B

Exit Interviews

Open-ended Questionnaire and Response Summary (Crew Member)

This appendix contains both the Crew Member and the IP Evaluator Open-ended Questionnaire and Response Summary.

I. Introduction

This form is to be used to structure the exit interview for the participants in the crew coordination research project, October - November 1993. Questions, both closed-ended and open-ended, are an integral part of the project data collection plan. Closed-ended questions are issued separately. The open-ended questions attached to this form are intended to be conversation starters and are not meant to limit free discussion.

Important

There are no "right" or "wrong" answers. We are asking for your honest opinions so that we can identify the relative contribution of battle rostering and standardized crew coordination training to flight safety and mission performance.

II. General

1. What is your AH-64 crew duty position? Pilot CPG
(Circle one)
2. How much experience in the AH-64 do you have in this duty position? _____ hours
3. Approximately how long have you been battle rostered with the crew member you flew with during the research project?
Less than 30 days _____ 60 - 90 days _____
30 - 60 days _____ More than 90 days _____
4. Approximately how many hours have you flown in the last:
90 days? _____ hours 180 days? _____ hours
5. Approximately what percent of the time do you fly with your battle-rostered crew member? _____ percent

6. Cross-indexing code: _____ (Last 4 digits of SSN)
(Note: Exit interview results will be correlated with other measures)

7. Do you believe that you performed better as a crew with your battle-rostered crew member or other crew member?

Summary: Mixed opinion. Crew members believe that factors like individual skills, experience level, and familiarity with other crew members contribute more to crew performance than whether crews are battle rostered or mixed. Aviators stated that mixed crews were better at crew coordination; that is, more cross monitoring and less complacency.

Specific Comments:

- Definitely better as a battle-rostered crew. Another crew member disagreed.
- After you've flown with someone for awhile, you start thinking in synch and you don't have to tell each other what to do.
- There is better flow with a battle-rostered crew member; not as much talking in the cockpit. Some non-verbal information [symbology] is shared within the aircraft system.
- The first few flights with your battle-rostered crew member, you cross monitor more. Initially, you try to cross monitor to sense out the other guy.
- With your battle-rostered crew member, you tend to be a lot more implicit in your coordination. With a mixed crew, you have to discuss more things.
- Some complacency is found with battle rostering. Flying with other crews guards against complacency. You learn things from different aviators.
- Coordination was better in the mixed crew, even though we performed adequately in both cases. The other crew member in a mixed crew listened better than the battle-rostered crew member.
- In another crew, they did as good with a mixed crew as they did with a battle-rostered crew.
- Overall, there was no difference in tactical performance.
- Performance depends on the level of experience of the crew, not the fact that they are battle rostered. Others agreed.
- If you have a good front seater, half your work is done regardless of whether or not he is your battle-rostered buddy. There is more frustration with a weaker front seater. The same is also true with the back seater.
- Familiarity is a big factor. If skill is equal, then familiarity can enhance performance.

- Tactical performance was based on level of experience and familiarity with the equipment. I can jump in with anybody in the unit and fly the same level of performance.
- It depends on personalities and whether or not you have conflicts in the cockpit.
- Battle rostering is done for convenience, not because we complement each other in personality or skill level. If you complement one another, you fly better; but this is not always the case in battle-rostered crews.

Conclusions:

- Verified that all crews were more verbal since they were being evaluated on crew coordination.
- Confirmed that aircrews are concerned about the potential for complacency within battle rostered crews.
- Included individual skills, experience, and familiarity as dimensions in analysis of research data.

8. What, if anything did you do or notice when flying with your battle-rostered crew member that you didn't do or notice when flying with another unit aviator?

Summary: General agreement that there is more explicit crew coordination and deliberate adherence to procedures when flying with other than a battle-rostered crew member.

Specific Comments:

- More assertive with battle-rostered crew member.
- With a battle-rostered crew member you can sense the urgency in their voice better.
- With a battle-rostered crew member, a lot of the procedures become subconscious (outside of awareness), as compared with a mixed crew (where you consciously think about procedures). The same thing happens when you don't fly for ten days. The first time back you follow all of the procedures more consciously.
- When you have to swap out with another crew, you'll not be as proficient in procedures. You perform better as a battle-rostered crew, but worse when you fly mixed because of the lack of conscious experience with following the procedures.
- There was more cross-monitoring and prompting (providing information) with the mixed crew.
- They didn't rush the flow of the mission with a mixed crew. More deliberate with mixed crew. Didn't "shoot from the hip" as with battle rostered crew member.
- More information is passed with a mixed crew.
- You tend to be more explicit when you fly with a mixed crew.

- Didn't find much difference when flying with people I knew, as compared to unfamiliar crew members (lower comfort level with strange crew member).
- You're more apt to watch someone from another company, as compared with someone from the same company (even though I haven't flown with the other guy from my company). Different companies have different SOPs, personalities, etc.
- Some found it easy to fly with another company, as long as standardized terms, etc were used.
- More things get forgotten or blown off when you're flying the aircraft instead of the CMS.

Conclusion:

- Included individual skills, experience, and familiarity with other crew member as dimensions in analysis of research data.

9. In whom did you have more confidence, your battle-rostered or nonbattle-rostered crew member? Why?

Summary: General agreement that confidence in other crew member is more a function of skills, experience level, and familiarity than whether the crew is battle rostered or mixed.

Specific Comments:

- I had more confidence in my battle-rostered crew member (slightly higher). This dissipated with time in the cockpit.
- You have about the same confidence in battle-rostered and mixed crew members. It is more a function of level of experience and proficiency of the other crew member (it takes you at least one mission to assess this).
- Others stated their confidence was a function of the other crew member's rank and experience.
- Confidence is influenced more by ability, rather than battle rostering versus mixed.
- With equal skills, your confidence is about equal. You watch weaker pilots more closely than stronger pilots.
- You gain confidence in others when they fly in the same flight (same company but not the same aircraft). You don't get this when you mix crews across companies. You tend to know who is who in the company level unit.
- Your confidence may be affected by how the other crew member communicates with you (do they reflect competence).
- Confidence can lead to over confidence and complacency. This wasn't seen in the experiment, but is seen in the field. The one time your battle-rostered buddy doesn't perform as expected comes as a big surprise.

Conclusions:

- Confirmed that aircrews are concerned about the potential for complacency within battle-rostered crews.
- Included individual skills, experience, and familiarity as dimensions in analysis of research data.
- Adverse affects of complacency, while relatively rare, can be very costly.

10. Did the rank, unit position, or experience of the other member of your crew affect how you operated as a crew member?

Summary: Strong agreement that the experience level of the other crew member had the biggest effect on how individuals operated as a crew member.

Specific Comments:

- Rank is a factor, but this depends on who you're flying with. Some pilots will hold back criticizing a commissioned officer.
- Rank can be a factor with more senior officers, but not junior officers.
- It would relieve cockpit stress if you didn't have to say "sir." You have to be on a more relaxed basis in the cockpit.
- Rank is more of a factor outside of the cockpit (e.g., planning), but this depends on individual personalities. You tend to be real formal when flying with your rater.
- Unit position can also influence responsibilities: you have to cover for the officer by doing more of the preflighting.
- Another aviator said he relied on his battle-rostered crew member because he was normally the mission commander.
- Experience is the big factor, not rank or unit position.
- I let the other crew member's experience level interfere with my PC actions in decision making and mission flow. I was less assertive.
- Experience has a big influence on your confidence level and how you operate as a crew member. When you fly with someone that you don't know how experienced they are, you're just not as confident.
- The other crew member's level of proficiency affects how much cross-monitoring you do.
- There was more cross-monitoring and cross-checking with low levels of intracrew confidence (even regarding aircraft control).

Conclusion:

- Analyzed research data to identify effect of experience level on crew performance.
- Rank intimidation in the cockpit is a persistent problem. Crew Coordination Training should emphasize the need to overcome entrenched cultural courtesy when operating as an aircrew.

11. Were you more formal or informal depending on whether you were flying with your battle-rostered or nonbattle-rostered crew member?

Summary: General agreement that there are differences with battle-rostered crews being more informal and mixed crews more formal ("by the book"). This difference is more pronounced during premission planning and rehearsal activities.

Specific Comments:

- More informal and implicit communications with battle-rostered crew member. More formal and explicit with mixed crew member.
- Battle-rostered crews accomplish mission planning and rehearsal more informally.
- A mixed crew might be more explicit, but not more formal.
- Mission briefing was more formal for both battle-rostered and mixed crews.
- Some thought there was no difference in formality, whereas others said a mixed crew caused them to be more formal (explicit) in their coordination techniques.
- Mixed crews resulted in more detailed and explicit exchanges.
- Attribute more formality to IP evaluation atmosphere not battle-rostered or mixed crew.
- There was a tendency in the experiment to be more formal, but in the field the crew briefing would be much shorter and more informal.

Conclusion:

- Included crew member self-rating exit interview items on crew coordination style (explicit versus implicit) in the analysis of crew performance data.

12. Were you able to identify any error chains during your missions? Were you better able to identify error chains with your battle- or nonbattle-rostered crew member?

Summary: Mixed opinion regarding ability to identify and break error chains.

Specific Comments:

- No differences noted by most of the aviators.
- You don't notice the error chain until the big disaster happens.
- With a battle-rostered crew, you can see things building more easily and intervene quicker.
- Battle-rostered crews were quicker to identify error chains because you had a better basis of comparison.

- More flags or vocal cues are recognizable with a battle-rostered crew.
- You know your battle-rostered crew member's strengths and weaknesses and can anticipate errors. With a mixed crew, you aren't as aware of where errors might occur.
- There is more willingness to challenge one another with a battle-rostered crew, as compared with allowing situations to develop with a mixed crew.
- With a mixed crew, you had to have several things go wrong before you began to see a pattern and intervene.
- With a mixed crew, you tend to continue the mission longer without raising an issue. Another crew member stated that he would be quicker to ask questions with a mixed crew.
- A mixed crew is also less willing to call out errors.
- With a mixed crew, I had more of a tendency to make a decision when things were going wrong (more assertiveness), whereas on a battle-rostered mission, I held back and waited for a discussion to ensue before a decision was made. This could be related to a lack of confidence in the other (mixed) crew member.
- I was more assertive in making a decision with a mixed crew.
- Breaking error chains depends on crew member assertiveness.
- The error chains in the CMS were short, as compared to being in a more dynamic field environment.

Conclusion:

- Included error chain observations made by data collection team members in the analysis of crew performance data.

13. What is (are) the advantage(s) of flying with your battle-rostered crew member now that all aviators in your unit have received the Army's standardized crew coordination training?

Summary: Mixed opinion. Advantages of crew familiarization achieved by battle rostering are outweighed by standardization of crew coordination training.

Specific Comments:

- There are advantages of familiarity and ability to anticipate and cut off error chains (knowing strengths and weaknesses of your battle-rostered crew member).
- Battle-rostered crews spend time together outside of the cockpit and develop close relationships. You know what's going on in their life, their personality, their mood that day; all beyond just flying together. You can sense when your crew member is not fully functional and should not be flying. When stuff starts going wrong, it's easier to talk.
- Battle rostering adds more familiarity and informality. It takes about 3-4 missions to gain the needed familiarity.

- Battle rostering might provide an advantage in that initial combat mission. Afterwards, there is no advantage to battle rostering.
- Battle-rostered crews are more informal and brief. Mixed crews operating by the book achieve higher levels of performance quicker.
- There are negligible advantages of battle rostering once you have had crew coordination training. Standardization improves performance across the whole unit.
- Crew coordination training provides a baseline of standardization.
- The crew coordination "shared experience" of the simulator training gives you better mental preparation; even for flights in the aircraft.
- Mandated battle rostering is a disadvantage.

Conclusion:

- Incorporated crew member opinions into battle rostering policy and crew coordination training policy recommendations.

14. What is your overall impression of the Army's practice of battle rostering aircrews? Do you have any suggested improvements?

Summary: General agreement that formally mandated battle rostering in conjunction with crew readiness level progression hampers unit flexibility to meet mission requirements. Battle rostering on an informal level is preferred over a formal system.

Specific Comments:

- You learn from other aviators, but you are more comfortable with and prefer to fly with your battle-rostered crew member on important missions.
- Just knowing someone in your company gives you confidence, as compared to flying with someone from another company.
- Everyone should be battle rostered, but everyone should go through the crew coordination training. The training provides effective ways of operating in the cockpit.
- Battle rostering builds complacency that can bite you some day.
- Battle rostering is not needed because crew coordination training forces you to standardize.
- Crew coordination training is more valuable than battle rostering.
- Battle rostering also takes away from the unit's versatility of flying with mixed crews. Mixed crew flights keep you alert.
- It is not worth the effort. It is too hard to rate. In the field, you won't remain with your battle-rostered crew anyway. It should be done informally, but not required in writing.

- You have to consider unit cohesiveness: you can launch quicker if you have a cohesive unit.
- Battle rostering on an informal level is preferred over a formal system.
- There are already too many other constraints on matching crews to missions.
- The formal program is difficult to implement in the unit. Units are hamstrung and discouraged from experiencing the training value of flying with different aviators. You should be able to fly with anyone in the unit.

Conclusion:

- Incorporated crew member opinions into battle rostering policy and crew coordination training policy recommendations.

15. What is your overall impression of the Army's practice of crew readiness level (CRL) progression? Do you have any suggested improvements?

Summary: Strong agreement that crew readiness level progression is an unnecessary administrative requirement.

Specific Comments:

- Prefer battle rostering, but do not want it to be a formal written policy for CRL progression.
- Eliminate CRL progression, but continue to fly with your battle rostered crew member.
- CRL is an unnecessary paper drill.
- CRL progression is a waste of time.
- Why should I have to artificially verbalize standard phraseology during a CRL progression check ride when I don't do it during routine missions? There is already too much communication in a mission, and it makes for a confusing cockpit. Others disagreed with this comment.

Conclusion:

- Incorporated crew member opinions into battle rostering policy and crew coordination training policy recommendations.

Open-ended Questionnaire and Response Summary
(IP Evaluator)

I. Introduction

This form is to be used to structure the exit interview for data collection team members in the crew coordination research project, October - November 1993. Questions, both closed-ended and open-ended, are an integral part of the project data collection plan. Closed-ended questions are issued separately. The open-ended questions attached to this form are intended to be conversation starters and are not meant to limit free discussion.

Important

There are no "right" or "wrong" answers. We are asking for your honest opinions so that we can identify the relative contribution of battle rostering and standardized crew coordination training to flight safety and mission performance.

II. General

1. What was your job on the data collection team? (Circle one)

Evaluator Data Collector
CMS Instructor Operator
Data Logger Collector
Workload Data Collector

2. Approximately how many missions did you observe and/or collect data?

_____ missions

3. Cross-indexing code: _____ (Last 4 digits of SSN)
(Note: Exit interview results will be correlated with other measures)

III. Open-ended Questions

4. Do you believe that crews performed better when battle rostered or mixed? Why?

Summary: Mixed opinion. Evaluators believe that individual and crew proficiency contribute more to crew performance than whether the crews are battle rostered or mixed.

Specific Comments:

- Battle-rostered crews had well established crew climates and were familiar with each other.
- Mixed. Mixed crews appeared to be more communicative and less complacent.
- Mixed crews definitely coordinated better, but it is hard to say that this resulted in better mission performance.
- Mixed crews talked more, but overall accomplishment of tactical objectives was more a function of crew proficiency.
- No significant differences were observed in overall performance.
- There is a fine line between a crew coordination problem and an individual proficiency problem that is hard to tease out in evaluations.
- You try to achieve a balance in proficiency when you battle roster. In mixed crews, you end up with really strong pairings and really weak pairings.
- Some crew members incorrectly perceived that lots of communication was needed to be evaluated at a high level.
- Verbal communication is not needed when the AH-64 system's shared symbology provides a certain level of nonverbal cross monitoring.
- In stressful situations, you will always have two separate cockpits and very little communication.
- There is a danger that standardized call outs, required in check flights, will become thoughtless exercises defeating their intended purpose.

Conclusion:

- Identified the importance of analyzing the contribution of crew coordination to ATM task performance as a means to focus on proficiency issues.
- Included individual skills, experience, and familiarity as dimensions in analysis of research data.

5. What, if anything did you notice the crews do when flying with their battle-rostered partner that they did not do when flying with another unit aviator?

Summary: General agreement that battle rostered crews tend to communicate implicitly and abbreviate mission planning and rehearsal.

Specific Comments:

- Implied communication and implied tasks were much more prevalent with battle-rostered crews, as compared with mixed crews.
- Battle-rostered crews used much shorter statements to communicate ideas.
- There was a greater comfort level with battle rostering, but this did not produce performance differences.
- Battle-rostered crews knew each other in the flight environment.
- Battle-rostered crews tended to abbreviate mission planning with comments such as, "Like we always do." When pressed for details, for example, emergency procedures and egress from a battle position, crew members did not have a common understanding.
- I had the sense that battle-rostered crew members spent time contemplating what each other was thinking or was responsible for before taking action.
- Mixed crews were more explicit in communications, both internal and external, and making task assignments.
- Mixed crews conducted more detailed planning and crew briefings.

Conclusion:

- Included individual skills, experience, and familiarity as dimensions in analysis of research data.
- Abbreviated planning and omission of "by the book" callouts are persistent problems to be addressed by crew coordination training.

6. Did the rank, unit position, or experience differences between crew members affect how crews operated? Did it affect crew performance? Examples?

Summary: General agreement that rank and experience affected crew performance.

Specific Comments:

- Yes, rank and experience differences were important: two classic examples were seen in the flights.
- Lack of assertiveness on the part of the junior crew member was the problem.
- PCs didn't want to tell higher ranked or more experienced crew members about errors.
- Yes, excessive professional courtesy.
- In combat, though, you need a definite cockpit gradient in order to make unpopular decisions.
- Did not notice any effect at all.

- The biggest factors that influenced the outcome of the missions were a) the pilot's PNVIS flight proficiency, b) the CPG's weapon system proficiency, and c) both crew member's situational awareness. All three factors correlate directly with experience.

Conclusions:

- Analyzed research data to identify effect of experience level on crew performance.
- Rank intimidation in the cockpit is a persistent problem. Crew coordination training should emphasize the need to overcome entrenched cultural courtesy when operating as an aircrew.

7. Were crews more formal or informal depending on whether they were battle rostered or mixed? Examples?

Summary: Strong agreement that there are differences with battle-rostered crews being more informal and mixed crews more formal or "by the book". This difference is more pronounced during premission planning and rehearsal activities.

Specific Comments:

- Battle-rostered crews were more informal, complacent, and overlooked things. Mixed crews were more formal, attentive, and did not overlook things as much.
- In battle rostering, when nothing gets said (because it is implicitly understood), nothing ultimately gets done.
- Mixed crews were definitely more formal in planning and rehearsal and crew briefing.
- Mixed crews were more formal in procedural aspects.
- Mixed crews seemed to ask more questions of each other during the flight.

Conclusions:

- Included self-rating exit interview items on crew coordination style (explicit versus implicit) in the analysis of crew performance data.
- Crews should be repeatedly reminded to operate "by the book" and not make a lot of assumptions about their fellow crew member's responsibilities, duties, and actions.

8. Did you observe any significant difference between battle-rostered and mixed crew performance of specific ATM tasks? Which ATM tasks?

Summary: Mixed opinion regarding significant difference in crew performance of ATM tasks other than mission planning.

Specific Comments:

- Mission planning was different. Mixed crews were definitely more detailed and deliberate.
- Mixed crews performed better in terrain flight navigation.
- Battle-rostered crews performed firing position operations better than mixed crews.
- Mixed crews appeared to perform better in the following ATM task areas: a) PNVIS flight, b) navigation, c) CPG weapon system operations, and d) instrument approach procedures.

Conclusion:

- Considered comments in analysis of ATM task research data.

9. Did you notice any difference in the type, frequency, and/or duration of crew error chain patterns between battle-rostered and mixed crews? Examples?

Summary: Mixed opinion regarding ability to identify and break error chains.

Specific Comments:

- Quicker detection of error chains with battle-rostered crews was purely a perception on the part of the crews. In reality, battle-rostered crews did not catch errors any sooner than mixed crews.
- No difference in time to resolve errors.
- When mixed crews made an error, it seemed to propagate into larger or additional errors.

Conclusion:

- Included error chain observations made by data collection team members in the analysis of crew performance data.

10. What is (are) the advantage(s) of battle rostering aircrews after all aviators in a unit have received the Army's standardized crew coordination training?

Summary: General agreement that battle rostering helps reduce risk by balancing differences in individual experience levels within units.

Specific Comments:

- There are no advantages to battle rostering except to balance experience levels.
- Accommodates large dispersions in individual proficiency within a unit.
- Familiarity with other crew member personality traits and behaviors in the aircraft environment.
- Battle rostering will help a deploying unit transition into combat.

Conclusion:

- Incorporated crew member opinions into battle rostering policy and crew coordination training policy recommendations.

11. What is your overall impression of the Army's practice of battle rostering aircrews? Do you have any suggested improvements?

Summary: General agreement that formally mandated battle rostering adversely affects unit safety and flexibility to meet mission requirements.

Specific Comments:

- Battle rostering is good. Keep battle rostering along with crew coordination training.
- Right now, battle rostering is an Army policy that is detracting from unit safety rather than improving it.
- Remove all mandatory requirements for battle rostering from regulation. Mandated battle rostering is a disaster. Don't mandate it under a title or it will be interpreted as regulation.
- Battle rostering doesn't allow the unit to maximize proficiency and mission performance. The unit is more important than the individual crews.
- Battle rostering is little more than a means to save training dollars. Crew members should be proficient in both AH-64 stations and should be given sufficient hours to do so. Mixed crews offer greater flexibility and safety.
- Battle rostering impedes unit mission performance by limiting crew selection and mission assignments when rigidly enforced.
- If implemented informally as part of risk assessment and unit training management, give it another name like "crew management or crew selection process."
- Drop all reference to the term battle rostering and let IPs and commanders make crew selections based on crew member experience, proficiency, and personality.
- Battle rostering should be informal and left up to the unit commander to implement.

Conclusion:

- Incorporated crew member opinions into battle rostering policy and crew coordination training policy recommendations.

12. What is your overall impression of the Army's practice of crew readiness level (CRL) progression? Do you have any suggested improvements?

Summary: Strong agreement that crew readiness level progression is an unnecessary administrative requirement.

Specific Comments:

- Requirement is a waste of time and paper and should be deleted.
- Replace CRL progression with crew coordination training.
- The ripple effect of replacing one crew member makes the CRL progression impractical.
- Consider replacing CRL progression with crew coordination training, gunnery table 8, and the crew conduct of fire trainer (C-COFT).
- CRL progression is not needed once crew members are trained in the crew coordination basic qualities.
- CRL progression is creating problems and will continue to cause problems in the future.
- Crew coordination training negates the need for CRL progression.

Conclusion:

- Incorporated crew member opinions into battle rostering policy and crew coordination training policy recommendations.